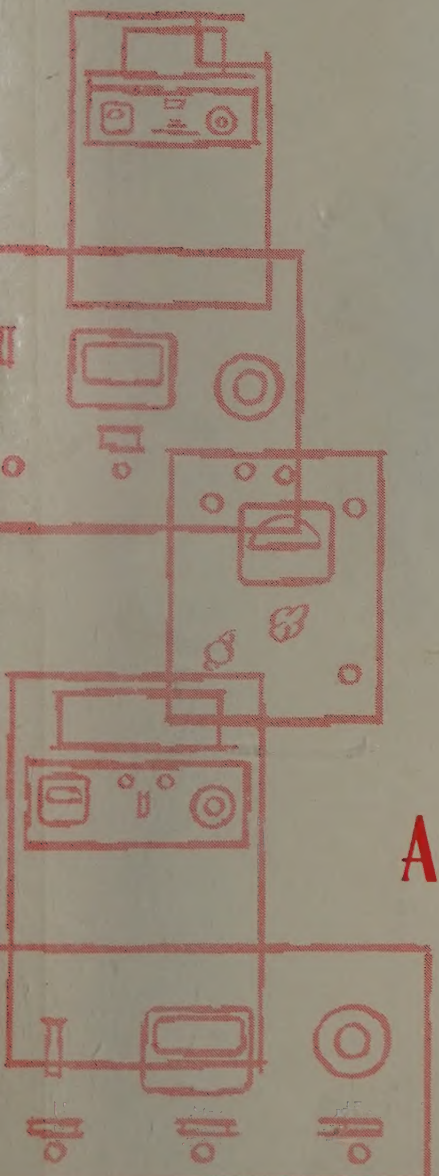

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# ASSOCIATED RESEARCH, *Incorporated*

3758 WEST BELMONT AVENUE • CHICAGO 18, ILLINOIS

MP MASTER
MA30112

## INSTRUMENTS *for measuring:*

- Insulation Resistance . . the VIBROTEST®
- Ground Resistance . . the VIBROGROUND®
- Earth Resistivity . . the VIBROGROUND®
- High Voltage Breakdown, AC-DC . . the HYPOT®

# OPERATING INSTRUCTIONS

# MODEL 421 - BENCH D. C. HYPOT

# 10 KV - 500 UA

## CAUTION HIGH VOLTAGE

THE OPERATOR IS RESPONSIBLE FOR THE SAFETY OF ALL PERSONNEL WHILE USING THIS INSTRUMENT. DO NOT ATTEMPT TO CONNECT OR DISCONNECT ANY ITEM UNDER TEST WHILE THE INSTRUMENT HIGH VOLTAGE IS ENERGIZED. KEEP ALL PERSONNEL A SAFE DISTANCE FROM THE HIGH VOLTAGE OUTPUT WHILE MAKING HIGH VOLTAGE TESTS.

CAUTION!

TO REMOVE HYPOT FROM CABINET REMOVE REAR PANEL FIRST AND DISCONNECT H. V. AND GROUND LEADS FROM BUSHINGS. THE ENTIRE CONTROL PANEL AND CHASSIS MAY THEN BE REMOVED FROM THE CABINET AS A UNIT.

ASSOCIATED RESEARCH
Incorporated

Manufacturers, Engineers, Consultants

3758 WEST BELMONT AVENUE • CHICAGO 18, ILLINOIS • PHONE CORNELIA 7-4040

# OPERATING INSTRUCTIONS
# MODEL 421 HYPOT

## FOR USE ON 60 CYCLE, 115 VOLT SUPPLY

1. Connect Hypot to 115 volt, 60 cycle supply and attach GROUND CLIP to a good ground.

2. Make sure VOLTAGE control knob is in the zero position (fully counter-clockwise).

3. Set current switch to the Neon position.

4. Connect test item to output terminals on top of case. (The NEGATIVE terminal is grounde to the case).

5. Switch power ON.

6. Switch high voltage ON and increase voltage to the desired value.

7. If the leakage light glows steadily, the output current (leakage current) exceeds 0.5 milliamperes D.C.

8. If the leakage light does not glow, set current switch to the meter position and read the value directly in microamperes on the microammeter.

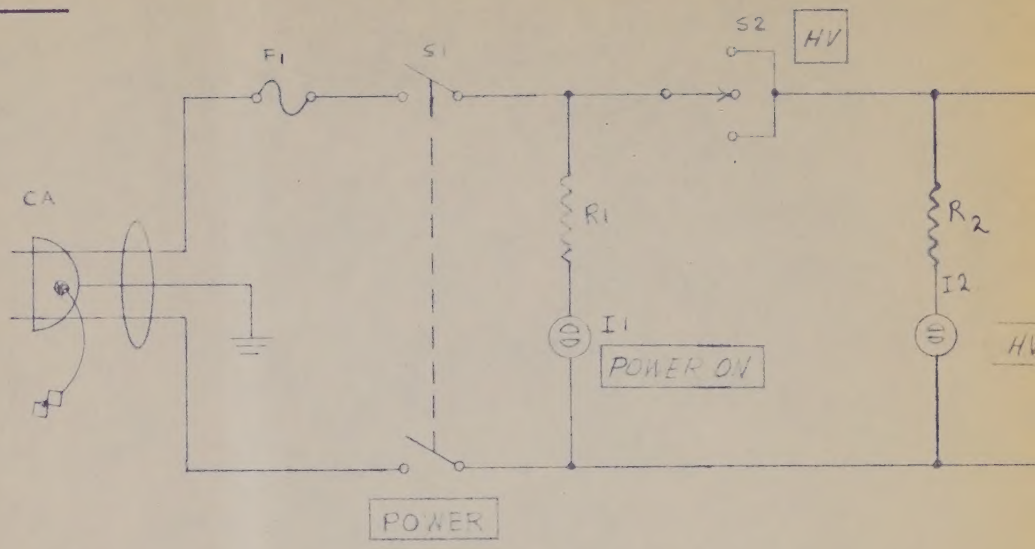
   The microammeter is automatically protected against short circuit overload at all times. In addition, this HYPOT is protected by a 2 amp fuse type 3AG. Access to this fuse is at rear of cabinet.

## ADJUSTMENTS

The adjustment for the leakage lamp is under a small white plastic snap plug located about an inch below the leakage light on the control panel. This control is adjusted so that the leakage indication light will glow at 0.5 milliamps D.C. The CURRENT SWITCH must be in the NEON position to adjust this control.

CIS-315-421-57
March 17, 1959

USED ON

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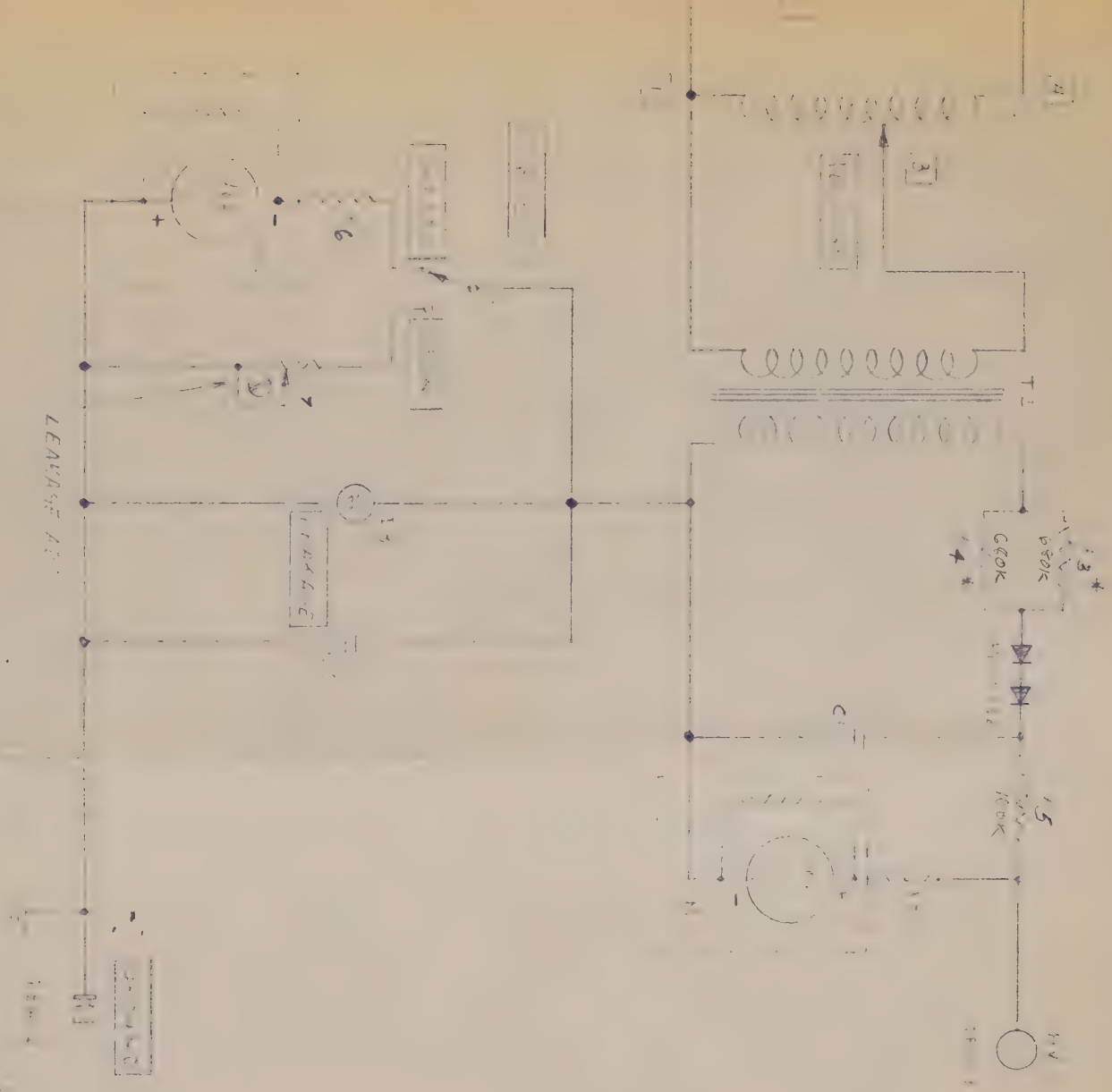

STARTING WITH SER # 421

NOTE: ELIMINATED R3 & 4 INSTRUMENTS STARTING WITH SER. # 89

| CHANGE | DATE | BY | APP. |
|---|---|---|---|
| ORIGINAL ISSUE | | | |
| ADDED NOTE REFERRING TO R3 & 4 | | | |
| [illegible] | | | |
| | | | |
| | | | |

TOL. FRACT. ±
DECIMAL ±
SCALE
MAT'L
FINISH
TOOLS

**ASSOCIATED RESEARCH, Incorporated**
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SCHEMATIC WIRING DIAGRAM
MOD. 421 HYPOT

DWN. | APP.
CKD. | SHT. 1 OF 1

DWG. # [illegible] C

198GL-B

VG. # A 3562

USED ON

MODEL 421
SCHEMATIC WIRING DIAGRAM LEGEND & REPLACEMENT PARTS LIST

| SYMBOL | PART NO. | DESCRIPTION |
|---|---|---|
| $C_1$ | P11875 | Capacitor, .05 mfd @ 10 KV |
| $C_2$ | P5609 | Capacitor, .05 mfd @ 400 V. |
| CA | P11649 | Cable Assembly, Input Power |
| F | P107 | Fuse, 2 amp, 3 AG |
| $I_1$ | P14160 | Indicator, "Power On" |
| $I_2$ | P14159 | Indicator, "H. V. On" |
| $I_3$ | P11189 | Indicator, "Leakage" |
| $M_1$ | 10381 | Meter Assembly, "Kilovolts", less multiplier |
| $M_2$ | 10383 | Meter Assembly, "Microamps" |
| $R_{1, 2}$ | P7031 | Resistor, fixed; 100K, 1/2 W., ± 10% |
| * $R_{3, 4}$ | P10196 | Resistor, fixed; 680K, 2 W., ± 10% |
| $R_5$ | P13109 | Resistor, fixed; 100K, 20 W., ± 10% |
| $R_6$ | P11903 | Resistor, fixed; 75K, 1 W., ± 5% |
| $R_7$ | P8671 | Resistor, variable; 150K, 1 W., "Leakage Adjust" |
| $RECT_{1, 2}$ | P10866 | Rectifier, Selenium, H. V. |

| | | |
|---|---|---|
| $S_2$ | P10637 | Switch, SP 2 pos., "H. V." |
| $S_3$ | P10464 | Switch, wafer, "Current" |
| $T_1$ | P11654 | Transformer, variable, "Voltage" |
| $T_2$ | P11663 | Transformer, H. V. |
| $TER_1$ | P10934 | Terminal, "H. V." |
| $TER_2$ | P11817 | Terminal, "Ground" |
| $R_8$ | P11935 | Resistor, 40 meg, 5 W., ± 1% |

*Note: Eliminated R3 & 4 in instruments starting with Serial No. 89

| | CHANGE | DATE | BY | APP. |
|---|---|---|---|---|
| | Added note referring to R3&4 | 2/7/62 | BZ | |
| | ORIGINAL ISSUE | | | |

TOL. FRACT. ±
DECIMAL ±
SCALE
MAT'L
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TOOLS

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MODEL 421
W. D. LEGEND & REPLACEMENT PARTS LIST

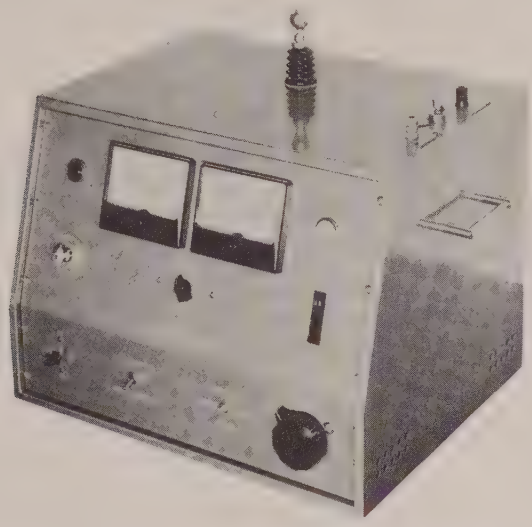
DWN. WM | APP.
CKD. | SHT. 1 OF 1

DWG. # A 3562 -C1L

E 198GL-6

ASSOCIATED RESEARCH, Incorporated
"Electrical Testing Instruments Since 1936"
ENGINEERING DATA SHEET

# BENCH TYPE DC HYPOTS



MODEL 5250 IN NEW BENCH CABINET

| MODEL | OUTPUT (KV) | CURRENT RANGES |
|---|---|---|
| 424 | 0-5 | 0-5/10/50/100 MICROAMPERES |
| 5200 | 0-5 | 0-50/250/2500 MICROAMPERES |
| 5401 | 0-5 | 0-50/500/5000 MICROAMPERES |
| 5603 | 0-5 | 0-.1/1/10 MILLIAMPERES |
| 5801 | 0-5 | 0-.25/2.5/25 MILLIAMPERES |
| 421 | 0-10 | 0-500 MICROAMPERES |
| 5011 | 0-10 | 0-50/500 MICROAMPERES |
| 5210 | 0-10 | 0-50/250/2500 MICROAMPERES |
| 5411 | 0-10 | 0-50/500/5000 MICROAMPERES |
| 5610 | 0-10 | 0-.1/1/10 MILLIAMPERES |
| 5810 | 0-10 | 0-.25/2.5/25 MILLIAMPERES |
| 5230 | 0-20 | 0-50/250/2500 MICROAMPERES |
| 5430 | 0-20 | 0-50/500/5000 MICROAMPERES |
| 5630 | 0-20 | 0-.1/1/10 MILLIAMPERES |
| 5831 | 0-20 | 0-.25/2.5/25 MILLIAMPERES |
| 5250 | 0-30 | 0-50/250/2500 MICROAMPERES |
| 5450 | 0-30 | 0-50/500/5000 MICROAMPERES |
| 5650 | 0-30 | 0-.1/1/10 MILLIAMPERES |
| 5270 | 0-45 | 0-50/250/2500 MICROAMPERES |

## CABINET DETAILS

DELUXE GRAY HAMMERTONE BENCH CABINET WITH BLUE HAMMERTONE SLOPING PANEL. WIDTH: 20"; DEPTH: 16-1/4"; HEIGHT (TO TOP OF CABINET): 14-3/4"; WEIGHT: 40 TO 75 POUNDS, DEPENDING ON RATING.

-- CONTINUED --

## GENERAL FEATURES

INPUT: 115 V, 50-60 CPS AC THROUGH FIVE FOOT, THREE CONDUCTOR INPUT LEAD WITH STANDARD TWO-PRONG PLUG AND GROUND CLIP.

OUTPUT: CONTINUOUSLY ADJUSTABLE FROM ZERO TO MAXIMUM. CURRENT SPECIFIED IS MAXIMUM RATED CURRENT AT ANY VOLTAGE. RIPPLE IS LESS THAN 5% AT RATED VOLTAGE AND CURRENT WITH RESISTIVE LOAD; LESS WITH A CAPACITIVE LOAD. HV OUTPUT TERMINATES IN HV BUSHING WITH CORONA BALL.

CONTROLS: ON-OFF SWITCH WITH PILOT LIGHT; HV ON LEVER SWITCH (MAY BE SET FOR MOMENTARY OR SUSTAINED CONTACT BY MEANS OF A KEY); HV ON PILOT LIGHT; OUTPUT VOLTAGE CONTROL; MA METER RANGE SELECTOR SWITCH; SELECTIVE GROUND SWITCH FOR GROUNDING METERED RETURN OR BYPASS RETURN TERMINALS TO ALLOW MEASURING EITHER LOAD (LEAKAGE) OR BYPASS (GUARD) CURRENTS.

METERING: 4-1/2" KILOVOLTMETER CONNECTED DIRECTLY ACROSS HV OUTPUT; ACCURACY 2% OF FULL SCALE. 4-1/2" ELECTRONICALLY PROTECTED CURRENT METER; ACCURACY 2% OF FULL SCALE.

SAFETY FEATURES: ZERO RETURN INTERLOCK; CONNECTOR FOR REMOTE SAFETY INTERLOCK; MANUALLY RESET CIRCUIT BREAKER PROTECTION ON BOTH HIGH AND LOW VOLTAGE CIRCUITS; LONG-LIFE SELENIUM RECTIFIERS; METERS ON GROUNDED SIDE OF HV; CABINET AND PANEL GROUNDED.

## SPECIAL FEATURES

VOLTMETER CONNECTED DIRECTLY ACROSS HV OUTPUT SO READINGS ARE OF ACTUAL TEST VOLTAGE APPLIED, IRRESPECTIVE OF REGULATION. OUTPUT CONTINUOUSLY VARIABLE FROM ZERO TO MAXIMUM VOLTAGE. ZERO RETURN INTERLOCK REQUIRES THAT VOLTAGE CONTROL BE RETURNED TO ZERO AFTER RELEASING HV SWITCH BEFORE HV CAN BE REAPPLIED.

## OPTIONAL FEATURES

1. ADJUSTABLE CIRCUIT BREAKER.
2. VACUUM TUBE MICROAMMETER FOR CURRENT RANGES AS LOW AS 2 μA FULL SCALE (INCLUDED IN MODEL 424).
3. ADJUSTABLE HIGH LIMIT SHUT-OFF FOR VOLTAGE OR CURRENT.
4. ADJUSTABLE NEON LEAKAGE CURRENT INDICATOR (INCLUDED IN MODELS 421 AND 5011).
5. AUTOMATIC RATE OF RISE (SEE BULLETIN 4-65.1.)

## NOTE

MODELS 421, 424 AND 5011 DO NOT HAVE ZERO RETURN INTERLOCK BUT HAVE A PRIMARY CIRCUIT BREAKER AND COLLAPSING FIELD HV TRANSFORMER AS PROTECTIVE FEATURES. ALL OTHER UNITS HAVE PRIMARY AND SECONDARY CIRCUIT BREAKERS. THESE THREE MODELS DO NOT HAVE METERED RETURN AND BYPASS RETURN CONNECTIONS.

MODELS 421 AND 5011 ALSO HAVE AN ADJUSTABLE NEON LIGHT LEAKAGE INDICATOR.

MODEL 424 FURNISHED WITH HV OUTPUT JACK AND 5' TEST LEADS INSTEAD OF USUAL BUSHING.

INSTRUMENTS for measuring

ASSOCIATED RESEARCH, INC.
3758 W. Belmont Ave. Chicago 18, Illinois

• Insulation Resistance . . the VIBROTEST®
• Ground Resistance . . the VIBROGROUND®
• Earth Resistivity . . the VIBROGROUND®
• High Voltage Breakdown, AC-DC . . the HYPOT®
• Special Instrumentation for Laboratory, Production, and Maintenance Needs

ASSOCIATED RESEARCH, Incorporated
3758 WEST BELMONT AVENUE CHICAGO 18, ILLINOIS

# VIBROGRAM

## "DIRECT-CURRENT HIGH POTENTIAL INSULATION TESTING"

That the use of the DC hi-pot test is increasing as a valuable maintenance tool is witnessed by an article bearing this title in the May, 1957, issue of the IRON AND STEEL ENGINEER.

As this article is of interest not only to the steel industry but to any industrial electrical engineer concerned with the maintenance of rotating machines, we review it by quoting salient portions to show:

". . . high voltage testing is a satisfactory method of evaluating the conditions of motor and generator insulation . . . this procedure is helpful to the steel plant maintenance engineer . . .

"For many years insulation testing with a megger has been accepted practice for maintenance people. In recent years the availability of fairly small, compact high-voltage rectifiers for converting 110 volt, 60 cycle, to as high as 75-kv, d-c has led to the investigation of the condition of insulation on the windings of rotating machines by applying high voltage direct current to the windings and measuring the leakage current to ground.

"A d-c voltage is applied to the winding, with the ground side of our test set grounded to the frame of the machine. The leakage current is measured as this d-c voltage is varied from zero upward.

"The value of the voltage versus current are plotted as the test is run. On the horizontal axis of the graph paper is the d-c applied voltage scale. On the vertical axis is laid out the dependent variable, the current, in microamperes. When the maximum d-c voltage to be applied has been decided, the voltage scale is divided into even increments. The first d-c voltage increment is then applied. As the voltage is raised from zero to the first point, the ammeter will show the summation of the charging current and the leakage current. The time it takes for the charging current transient to die down is measured. After the current has become stable, it is recorded as well as the time interval required. The voltage is then raised to the second point and this procedure is repeated. The values of voltage and current are plotted and the curve is crawn as the test is run.

"The time interval of taking the reading is quite important. On relatively small motors with good insulation the current will stabilize very quickly.

"On large equipment, on the order of a 100,000 kw generator winding, once the total current has apparently stabilized, we proceed to the next point on the test, using even increments of time, even though the charging current may be still decreasing. The time intervals used are part of the techniques of this type of testing which can only be gained by experience.

"The interpretation of the curve as it is plotted is extremely important. Here again experience is needed. If the voltage versus current relation remains linear over the range which has been decided before the test was started, the test range can be extended.

"If the curve starts sweeping upwards rapidly, or shows signs of becoming unstable, the test should be stopped and an investigation made.

"A few examples of test curves on machines are interesting and informative.

"The test curve of Figure 5 is from a 75,000-kva, 138.5-rpm, 13.8-kv, 60 cycle hydro-electric generator which had been rewound. The test went to 30-kv, d-c in 5-kv increments. Voltages were held for ten minute readings. From one voltage step to the next voltage step took about one minute.

"A similar curve in Figure 6 is for a 450-hp Motor, 4150-volt, 60-cycle, 180-rpm. The stator windings on the machine were 30 years old but had been kept clean, dry and varnish treated.

"Data in Figure 7 is for a 300-kw armature and illustrates the quite marked change in resistance to ground which can be effected by good maintenance work."

The author continues with a brief discussion of the ratio of the equivalent DC to the standard AC test potential with the conclusion that this ratio appears to be between 1.5 and 1.6. He concluded the article:

"The Pacific Gas and Electric Co., one of the world's largest utilities has been using this method of testing for quite a few years. The Detroit Edison Co. also has described very extensive use of these tests. The conclusion arrived at by Detroit Edison is that d-c high voltage testing is a satisfactory method of evaluating the condition of generator insulation.

"It remains for the people in the steel industry to investigate this new concept and put it to use as an aid to steel production."

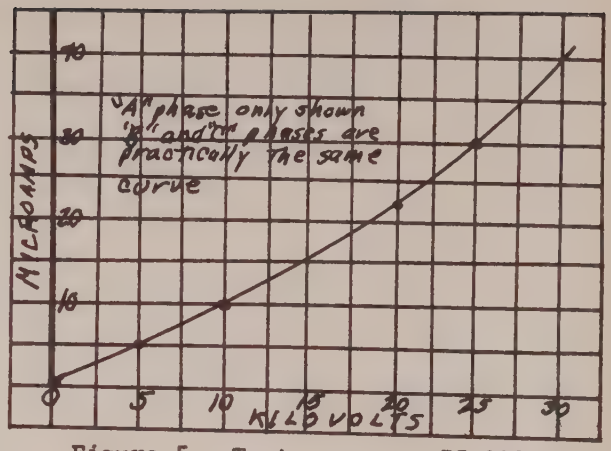



Figure 5 - Test curve on 75,000-kva hydroelectric generator after rewinding.

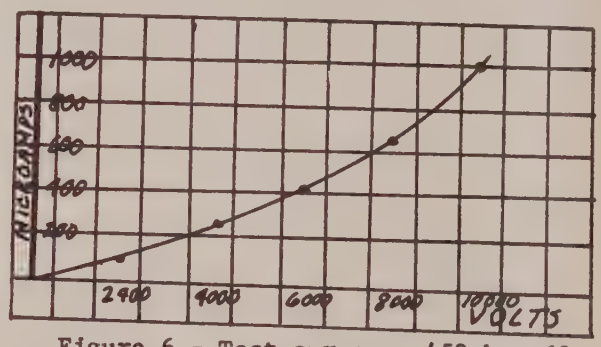



Figure 6 - Test curve on 450-hp, 60-cycle motor after 30 years service.

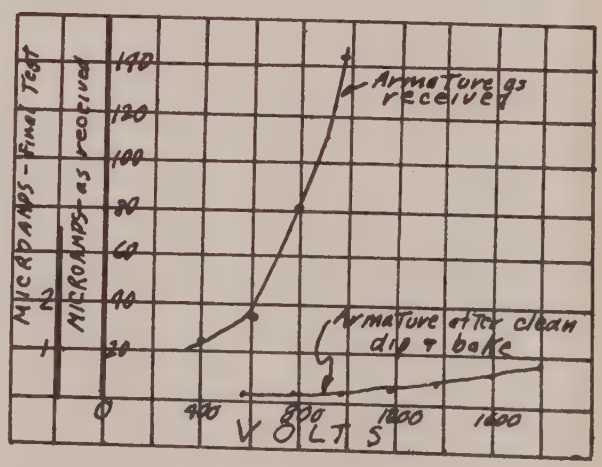



Figure 7 - Test curves show improvement effected by cleaning and baking armature.

Bulletin 5-15.4

ASSOCIATED RESEARCH, Incorporated
"Electrical Testing Instruments Since 1936"
INSTRUMENT APPLICATION NOTES

Reprinted from "ELECTRONIC DESIGN"
February 1, 1961.

# High-Voltage Testing: It Can Be Nondestructive

**Harold N. Miller**
Vice President and Chief Engineer
Associated Research, Inc.
Chicago, Ill.

IS HIGH-VOLTAGE testing destructive or nondestructive? Both sides of that question are amply covered in published articles; the answer would seem to lie, in any individual case, in the material being tested and the method of testing.

Intelligent appraisal of the subject first requires understanding breakdown mechanism, or at least the main causes of insulation failures. Insulation breakdown is usually described as: a destructive discharge through the insulation, characterized by a disproportionately large change in test current as test voltage is increased. This surge is often referred to as an avalanche current. After a breakdown failure, it is usually impossible to restore voltage to the previous point. Breakdown may also be defined as: a rupture of the insulation that results in increased leakage current at a specified test voltage.

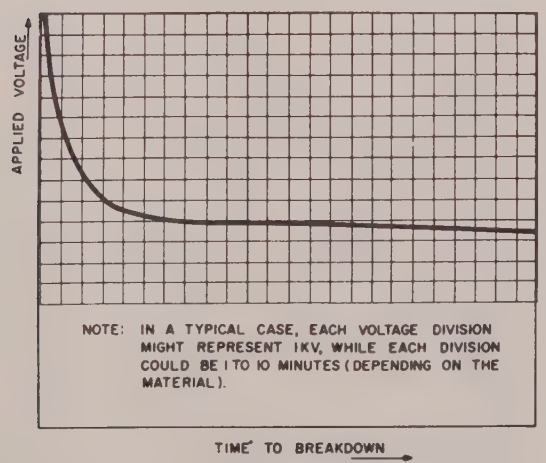

APPLIED VOLTAGE
NOTE: IN A TYPICAL CASE, EACH VOLTAGE DIVISION MIGHT REPRESENT 1KV, WHILE EACH DIVISION COULD BE 1 TO 10 MINUTES (DEPENDING ON THE MATERIAL).
TIME TO BREAKDOWN

**Fig. 1.** Applied test voltage versus length of time to breakdown.

### Causes of Insulation Breakdown: Three Are Cited

Three main causes of failure are usually identified as:

1. ***Mechanical breakdown,*** caused by stresses set up by the applied voltage. This type of failure is much more likely to be prevalent with ac testing than with dc; it is often associated with impulse testing.
2. ***Thermal failure,*** due to insulation deterioration caused by internal generation of heat. This heat may be due to high leakage current, but more often is caused by conductors or other current-carrying parts operating hot. Thermal damage is cumulative with time.
3. ***Ionization failure,*** due to chemical deterioration of the insulation. This is usually caused by oxygen released during ionization of air in insulation voids or around the insulation. Deterioration caused by this chemical action is cumulative with time.

Since two of the three main causes of insulation damage show a cumulative effect, indiscriminative testing can eventually cause failure. Testing, properly done, however, would not be carried to levels that would result in any significant damage to sound insulation.

### Voltage Endurance Can Serve As A Function Of Test Time

The voltage a piece of equipment can stand depends, to a great extent, on the length of time

that voltage is applied. This relationship is not linear, but has the general characteristics shown in Fig. 1. The exact shape of the curve (applied voltage vs length of time to breakdown) depends on the specific material under test, if the applied voltage is ac or dc, the shape of the test electrodes, etc. In all cases, however, the curve shows that, if the voltage is lowered slightly, the withstand time is increased greatly.

If the equipment is originally designed so the insulation can stand 120-130 per cent of the final test voltage for a reasonable length of time (several minutes to an hour), almost indefinite testing at the lower voltages can be done without damage. Recognizing this characteristic of insulation leads many specifying agencies and manufacturers to call for in-service test voltages of 60 per cent to 80 per cent of the factory test values. This voltage-vs-time condition is also specified or implied in many specifications that permit tests at a given voltage for 1 min or, alternatively, a 25 per cent higher voltage test for 5 sec. In the case of equipment already designed or in production, the test voltage the insulation can stand for the long time period can be experimentally determined. Then, running production or maintenance tests at 60 per cent to 80 per cent of this voltage would be safe.

With the present state of the art (where even thin films of insulation may stand many hundreds of volts per mil), it is almost mechanically impossible to have a sound insulation structure with a breakdown strength of less than a few thousand volts. Consequently, most test codes call for high-potential testing values of twice-rated voltage plus a 1,000-v for a period of 1 min. If the equipment is originally designed to stand a slightly higher voltage than this for a longer length of time, the damage that might be done at the test voltage is minute, and sound insulation would not be harmed even after hundreds of tests. If the test value is chosen too low, the test may as well not be made, for it will give a false sense of security.

### Minimizing Destructiveness By Current Limiting

When the voltage-withstand strength of equipment under test is not known or inconvenient to determine, current-limited high-voltage test equipment can be used to insure nondestructiveness of the dielectric strength test. The current limiting may either be in the form of (1) a fast-acting circuit breaker in the output of the test set (set to trip at a few milliamperes or less), or (2) a collapsing-field type high-voltage transformer that automatically lowers output voltage as load current increases.

With equipment of this type, the test voltage is lowered or removed before the insulation can

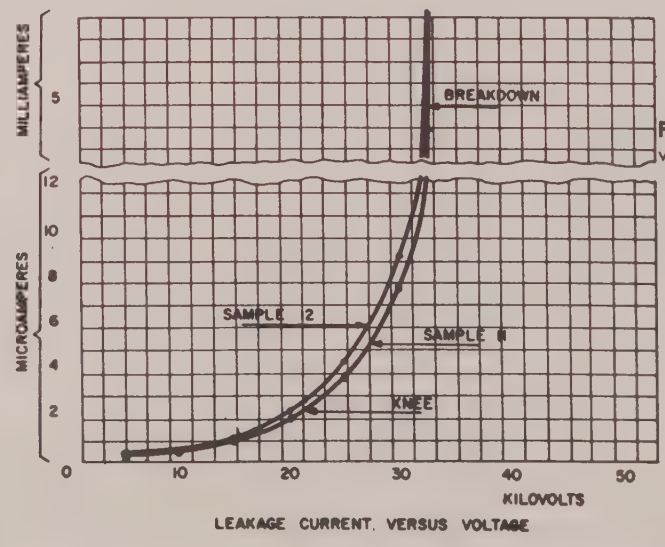



**Fig. 2.** Leakage current versus voltage.

rupture. Thousands of test sets of this type are in continuous use today, testing all types of consumer items without any evidence of causing equipment damage.

### Internal Corona Develops Due to Voids in Insulation

Often, in running a high-potential test, internal corona develops due to voids in the insulation, at voltages far below the breakdown voltage of the insulation itself. Unfortunately, the presence of this corona won't show up with most test sets in common use.

Corona produced during testing may rapidly deteriorate the insulation; since the effect of this deterioration is cumulative, subsequent high-voltage tests are usually blamed for failure. Note, however, the production of corona actually indicates a defect (usually a void) in the insulation; thus, the insulation could not be considered sound. When corona damage is significant in the equipment being tested, a high-potential test should be made, using modern corona detection equipment that displays the presence of even minute amounts of corona. Using this type of equipment, the high-voltage test could be stopped at the point of inception of corona, thus preventing harm to the insulation.

### DC High-Potential Testing Is an Important Consideration

Another very important consideration in the destructive or nondestructive aspect of high-potential tests is the relative results obtained with ac or dc. Ac testing is usually considered a go/no-go type of proposition. In other words, voltage is run up to a specified value; if the sample breaks down, it is no good; if it does not break down, it is assumed good.

Unless proper precautions are taken, there is no way of knowing how close the sample approaches the breakdown point. On the other hand, with dc testing, the procedure is somewhat different; leakage current is measured as voltage is raised. As long as current varies approximately linearily with test voltage, the equipment is in good condition. In most cases (this depends on the particular insulation materials involved) there will be a knee in the curve of voltage-vs-current, prior to breakdown. In other words, as the breakdown point is approached, the leakage current starts increasing at a higher rate; soon the avalanche current referred to above appears. On certain newer materials, this knee is almost a right-angle bend; breakdown is reached at about the same time the first sign of the knee appears. In many cases, however, the knee is gradual enough so that the change-of-slope of the current vs voltage current is apparent; if the test is stopped at that point, no harm is done and the test may be repeated almost indefinitely. Here we have a truly nondestructive test, because, regardless at what voltage deterioration starts to take place, the careful operator (in many cases) can end a test prior to any damage. Careful observation of the slope of the curve of leakage current-vs-applied voltage will yield valuable information about the adequacy, condition, and even expected life of the insulation.

### Rate of Application of Voltage Will Affect Breakdown Point

The method of voltage application will have some effect on the breakdown point. Most published data indicates that the slower the application of voltage, the more apt the failure to occur at a lower value. Note that in impulse testing of high-voltage insulators and transmission line equipment, voltages many times the normal high-potential test values are used. ASTM Specification D-149, Parag. 3, says, "In general, the dielectric strength decreases with time of exposure to the electrical stress." Appendix I to that same specification says, "The more rapid the increase in voltage, the higher will be the breakdown voltage."

### Typical Results Are Described

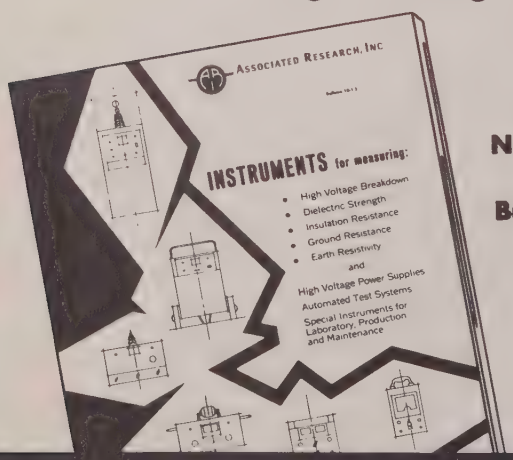
Despite the massive amount of data supporting the above explanation, additional tests were run at our firm under semicontrolled conditions (to simulate production testing rather than laboratory testing). Ac tests were run, using our model 4501 35-kv oil tester and a model 4505 35-kv materials tester. Dc tests were run using our Model 5265 15/30/45 kv dc Hypot. Various samples were tested, including transformer insulating oils, cellulose acetate film, polyethylene sheets, insulated wire, and simple subassemblies. Results of these test (three are summarized below) amply bear out this fact: properly conducted, high voltage test can be nondestructive.

*Test 1:* Tests were made on identical samples of transformer grade insulating oil, following the procedure in ASTM D877-49, "Test for Dielectric Strength of Insulating Oil." Fifteen samples of oil, used as a control group, were tested to determine the breakdown voltage. All fifteen broke down between 25 and 28 kv; average for the group was 26 kv. Sample No. 16 was tested by raising the voltage at 3 kv per sec up to 20 kv and rapidly dropping the voltage to zero for 100 times, at 2-min intervals. That sample was then tested to breakdown, which occurred at 28 kv; the sample finally broke down on the 88th test (at 25 kv). Sample No. 17 was tested at 22.5 kv for 150 times without failure. The test voltage was raised to 25 kv; the sample finally broke down on the 88th test (at 25 kv). Sample No. 18 was raised to 25 kv and held at that voltage for 1 min before returning to zero. This was repeated until breakdown occurred on the 21st test. Ten more samples were tested to determine the breakdown point. Breakdown in each case fell between 25 and 29 kv.

*Test 2:* Samples of 0.008-in. cellulose acetate tape were tested in accordance with ASTM Specification D1202-52T, "Cellulose Acetate Sheet and Film." Several control samples were tested to determine the average breakdown value (15 kv). Additional samples of the same material (taken from the same piece) were then given repetitive high-voltage tests, running up to 10,000 v at the rate of 500 v per sec, with rapid return to zero. These tests were repeated 50 times for each sample without failure. The test voltage was then raised until the samples actually broke down, which occurred between 16 and 17.5 kv for this group. Another sample of the same material was raised to 10 kv and the voltage left for 1 hr. The voltage was raised to 12.5 kv; breakdown occurred after 35 min.

*Test 3:* Samples of insulated cable were tested with dc. In each case, the voltage was raised to 20 kv; the leakage current was recorded. The control samples showed leakage currents between 1.5 and 2 μa at 20 kv. The voltage of sample No. 11 was increased until breakdown occurred at 32.5 kv. The voltage on sample No. 11 was increased until breakdown occurred at 32.5 kv. The voltage on sample No. 12 was raised to 25 kv and maintained for 2 hr before lowering. The cable showed no sign of damage, nor was there any measurable increase of leakage current during that period. The same sample was then tested 25 times at 20 kv, allowing suitable intervals between tests to permit complete discharge. On the 25th time, leakage current at 20 kv was still identical with the value recorded the first time. The voltage on the same sample was then raised to breakdown, which occurred at 32.5 kv. As shown in Fig. 2, the curve of leakage current-vs-voltage for sample No. 12 (which received a 2-hr test and 25 short tests) is almost identical to the curve of the control sample No. 11, which was raised to breakdown voltage on its first test trial. ■ ■


## High Voltage Breakdown Testing . . A-C or D-C




**NEW...**

**Bulletin 10-1.3**

A full range of instrumentation for non-destructive breakdown tests is offered. Pages 4, 5, 6 and 7 of this catalog describe each basic series. Page 11 gives data on automated systems for dielectric strength testing. Page 3 refers to instrumentation combining dielectric strength testing with tests that are frequently made concurrently.

Our experience as one of the largest and best equipped producers of heavy duty dielectric test sets has shown the need for wide variations in the facilities to be embodied in the individual test set.

Thus, basic HYPOT® designs presented on these pages are essentially for reference. Additional facilities required for specific applications may be incorporated. Many of the useful features described are available only in HYPOT® test sets. Provisions for material and equipment testing in accord with applicable ASTM, MIL, and Federal Specifications are provided by suitable HYPOT® models.

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# Practical Hi-Pot Testing

*The pet cliché of dielectric test-spec writers—"withstand without breakdown"—leaves a lot of room for interpreting test results. This vagueness, coupled with common misunderstandings of dielectric circuitry, can easily lead to false rejects. Here are some practical considerations for setting up both a-c and d-c high-voltage test stations.*

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CONSIDERING THE GREAT DIVERSITY of products that are electrically energized, it is not surprising that a wide variety of tests have been developed to meet specific needs of particular product groups. Current tests in use include high-potential testing (at power frequency), induced overvoltage tests, impulse voltage, insulation resistance, power factor, corona level, etc.

However, the two types in general use among all groups are the high-potential test and the insulation-resistance test. They are easy to apply and, in most cases, reasonably easy to evaluate. Also, test sets for this purpose are generally portable, reasonable in cost and suited to production line application, a factor of increasing importance.

The purpose of this article is to analyze the high-potential test as a means of evaluating the overall insulation quality of manufactured equipment. Actually, the high potential test has many other applications as well (*1*)* but this discussion will be limited to quality-control considerations only. The insulation-resistance test is different in nature and purpose and will not be treated here.

*Italic numerals in parenthesis refer to Cited References at end of article.

## A-C High-Potential Testing

There are normally two major purposes for dielectric testing: First, to determine that the equipment insulation meets a level known to be satisfactory by the manufacturer himself. (How to set up and evaluate such criteria will be discussed later.) Second, to determine that the equipment insulation meets a level defined in specifications (or "standards") of some outside group, which the manufacturer is committed to meet or is following. The familiar MIL specifications and Underwriters' Laboratories Standards, as well as those of ASA, NEMA, JIC, and others, are common examples.

The mushrooming growth of electrical manufacturing, with the consequent emphasis on production, plus the fact that in many cases the electrical testing is done on a primarily mechanical product, has resulted in a general reliance on tests made in conformance with outside standards as the primary means of exercising quality control. For really analytical testing this approach can leave much to be desired and in addition may actually

permit substandard equipment to be passed. This seemingly paradoxical situation exists because:

1. Specifications and standards which define dielectric test requirements generally cover application to a wide range of items, hence must be couched in general terms.
2. The characteristics of high-voltage alternating current in dielectric circuits limit the development of specific yardsticks, as will be shown.

Yet the demand for greater reliability in the vast and growing array of new electrical and electronic mechanisms and components is leading many manufacturers to seek to extend the scope of "hi-pot" testing beyond its present status as a simple "pass-fail" test as outlined in existing standards.

The wording of a typical standards specification will help illustrate the lack of a definitive starting point: Underwriters' Laboratories states that a commercial cooking appliance " . . . shall be capable of withstanding without breakdown the application of a 60-cycle alternating potential . . . ," etc. (2) Almost all existing standards for electrically energized equipment are worded in similar fashion.

While the concept appears easy to apply, in practice each manufacturer will usually find that he must define for his own application what the phrase "withstand without breakdown" actually means. As the complexity of modern insulating structures and the variety of insulating materials increase, a hard and fast definition of what does or does not "withstand without breakdown" becomes a rather tenuous thing. No further help on this question of interpretation can be found in any official source, to the author's knowledge.

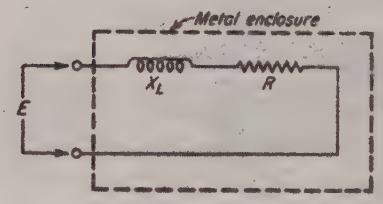
It is of course true that where an actual short circuit does exist in the insulation structure (zero insulation resistance at some point), the application of high voltage would produce a magnitude of current indicative of "breakdown." But how to detect the infinite variety of conditions which could exist between the completely defective insulating structure and a completely sound structure meeting the original design criteria?

The answer to this question lies in some fundamental considerations of alternating current circuit characteristics frequently overlooked.

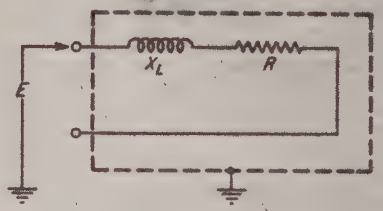
**Dielectric Circuits.** As illustrated in Fig. 1, the *dielectric* circuit encountered in hi-pot testing is quite unlike the *electrical* circuit of the device being tested. While the latter is most commonly a series inductive-resistance circuit, the dielectric test circuit is a parallel resistance-capacitance circuit. The resistance of the dieletric circuit is that of the insulation. The presence of shunting capacitance is to be expected, since the basic definition of a capacitor is two conducting surfaces separated by a dielectric. And the majority of high-potential tests are made between circuit conductors and other metal parts of the equipment that are insulated from each other. If the dielectric employed were a perfect insulator (infinite insulation resistance), the entire dielectric circuit could be represented as a perfect capacitor (ignoring absorption effects, which will be considered later).

Thus, the total current $I_T$ which would flow in the test circuit of Fig. 1 consists of two components: the capacitive charging current $I_C$ which leads applied voltage by 90 deg, and the true leakage current $I_R$ which flows through the insulation and is in phase with the applied

**Fig. 1—Fundamentals of Hi-Pot Testing**

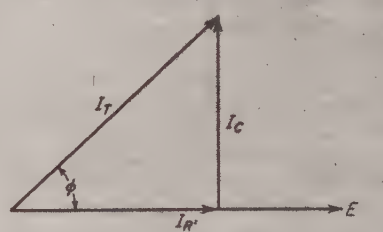



While most electrical equipment operates as an inductive load . . .

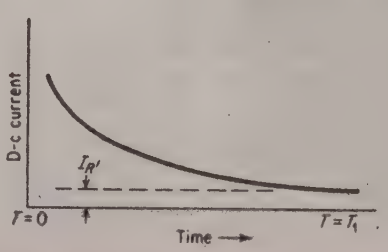



. . . the load presented to a high-potential dielectric tester . . .

. . . tends to be capacitive. For a-c tests the total test current is complex . . .

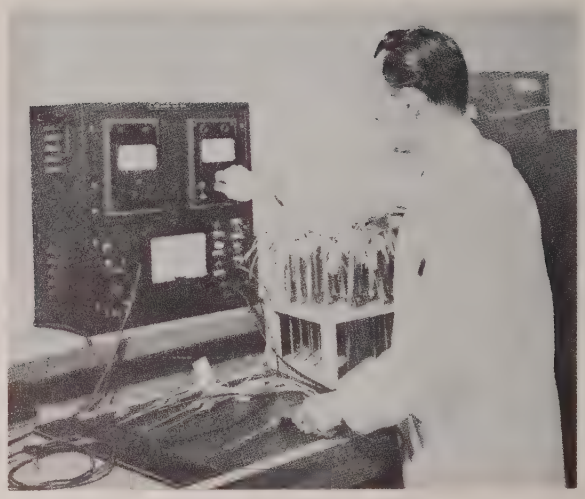



. . . and, for devices with highly capacitive geometry, may be much higher than true leakage current.




With d-c applied, test current decays to true leakage current, but testing time may increase considerably.

# Typical Test Stations for . . .



## . . . THERMOSTATS

Preliminary test panel for testing dielectric strength, insulation resistance and contact resistance of immersion-type thermostats. Unit incorporates standard high-potential a-c test set (upper right) and insulation-resistance test set (upper left)—both slightly modified with cases removed for panel mounting. Lower instrument is a multi-range ohmmeter. (*Fenwal Inc., Ashland, Mass.*)

voltage. For a given test voltage, the magnitude of $I_R$ will depend on the insulation resistance, and of $I_C$ on the circuit capacitance, which in turn is determined primarily by the geometric layout of the physical circuit. For example, a hi-pot test applied to a simple cord set (between conductors) would produce a current consisting almost entirely of $I_R$, since the conducting surfaces here would consist of only two short wires. The same test applied between widings and frame of a motor would produce a much larger current, primarily $I_C$, since we would have many turns of wire encased in a metal housing.

Critical laboratory analysis would show that there is actually a third component of current present known as the absorption current. (*3*) It can be visualized as a current which is actually "soaked up" by the dielectric, and is due to lack of homogeneity in the dielectric itself. The absorption current also has both a resistive component and a reactive (leading) one, thus tending to make the insulation resistance appear to be lower and circuit capacitance higher. Its magnitude depends on the nature of the dielectric and the frequency of the test voltage, but need not be compensated for in production testing.

An understanding of the complex current flow in a dielectric circuit under a-c high-voltage stress is important because, in the absence of visible or audible indication of breakdown, the current flowing in the circuit is the only major quantity left which is capable of interpretation. Thus the basic limitation of a-c testing can be summed up as follows:

1. The total current flowing is complex in nature and its magnitude does not necessarily depend on the condition of the insulation.
2. The total current flowing is *not* leakage current; leakage current is properly referred to as current flowing through the insulation, hence in phase with the applied voltage.
3. On highly capacitive equipment, a substantial change in insulation resistance would be required to produce a like change in the total current.

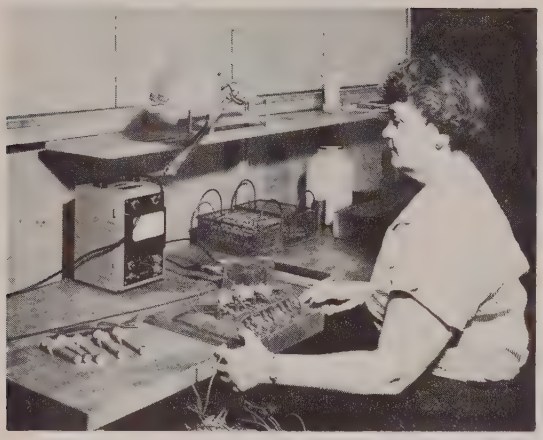
The circuit phenomena of a-c hi-pot tests have a direct effect on the requirements of equipment to perform these tests.

**A-C Test Equipment.** Any test set should meet the standard requirements of: transformer of sufficient capacity with a relatively pure sine wave output; continuously variable output voltage; voltmeter to accurately read output voltage at all times, etc. However, for practical quality control work there are several other very important requirements:

1. Obvious means should be provided to indicate defective equipment.
2. Defective units should be detected with a minimum of additional deterioration or destruction.
3. The test set should be suitable for production line applications.
4. The test set should be safe to use.

To date, two methods of indication have been built either singly or coincidentally into the smaller sets (under 5 kva)—an arc detector and/or a current-sensing device.

The first is a neon lamp connected across an r-f choke, usually connected in the ground side of the high voltage output and labeled "breakdown," "arcing," or "corona." This lamp operates on the principle that arcing ionizes the air sufficiently to induce a voltage across the choke to light the lamp (the ground lead acting as a carrier).



**. . . FIRE DETECTORS**

Simple fixture for gang testing of fire-detection units has two pushbuttons requiring the operator to use both hands to avoid accidental contact with hot leads while observing test meter. (*Fenwal Inc., Ashland, Mass.*)

**. . . SOLENOIDS**

Closeup view of simple dielectric test being applied to small solenoids for air conditioners. Tester includes variable autotransformer and voltmeter with breakdown, leakage and pilot lights. (*Spencer Thermostat Div., Metals and Controls Corp., Attleboro, Mass.*)

While no attempt has been made to precisely define the useful limits of this principle, under most conditions the lamp serves two useful purposes: (1) It will definitely indicate arcing, which in some cases might be otherwise undetectable to the operator; and (2) if the test voltage is applied slowly to an insulating structure including air, the initial ionization point of the air will be indicated by a faint glow, warning that impending breakdown is very near. The major drawback is a lack of indication for a failure not accompanied by arcing.

The second method of indication, using current-sensing devices, was first applied to small sets for testing toasters, coffee-makers, etc. The device consisted of a neon lamp connected across a variable resistor. When the total current flow through the resistor produced a sufficient voltage, the lamp indicated. On these small appliances the total current flow was almost entirely resistive and could therefore be considered true leakage current with negligible error. This lamp was commonly labeled a "leakage" light, and proved to be so useful that its application became increasingly popular. Because users tended to accept this general term literally, there were and are many instances of confusion caused by leakage indication on known good equipment which had sufficient distributed capacitance to draw a charging current exceeding the setting of the light. Under these conditions leakage indication may be entirely unrelated to actual leakage current flowing through the insulation. This difficulty is inherent in all current-sensing devices now in use, whether leakage lights, electronic "circuit breakers" or over-current relays.

However, such current-sensing devices can be used effectively in a production test setup by, first, estimating the average total dielectric current (at the test voltage) for acceptable samples and, second, specifying the setting of the current-sensing to be roughly twice this. This should be high enough to pass normal dielectric currents, yet low enough to detect defective insulation. Some adjustability of setting should be provided, particularly to raise the setting if the capacitive currents run higher than anticipated.

A simple tester such as this will be reasonably efficient where essentially duplicate items are tested. Where one unit is used to test such items as electrical motors in a wide variety of horsepower ratings, or varying lengths of wire or cable, a single current setting for all items may have to be so high to prevent false indication that its effectiveness will be materially reduced. Here a quick means for switching settings should be provided.

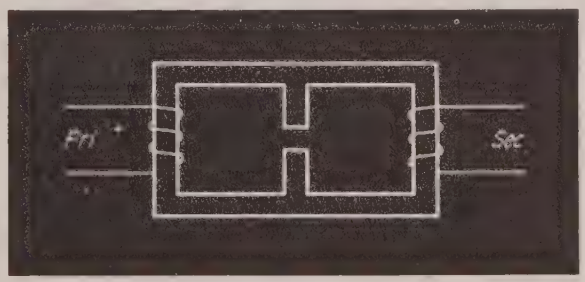
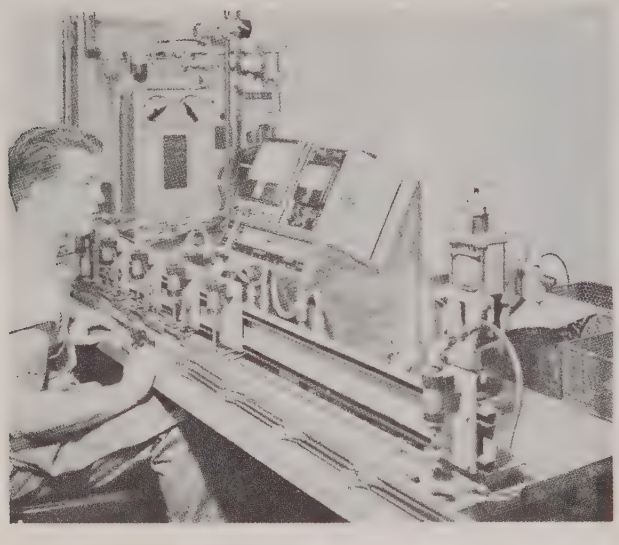



**Fig. 2—Magnetic-shunt center leg of high-leakage transformer in the output circuit of an a-c hi-pot tester limits output current when tested insulation starts to break down.**

## *Typical Test Stations for . . .*



### . . . WIRING HARNESSES

This particular test station does not include a hi-pot tester, but it serves to illustrate the degree of automaticity possible for such tests. Here, harness assemblies for gas-turbine thermocouples are pneumatically clamped and connected in the test circuit. Circuit-continuity tests and a 500-volt d-c insulation-resistance test are applied automatically. Necessary switching and indicating devices are built into the control unit, on which are mounted a multi-range ohmmeter and a standard insulation-resistance tester. (*Fenwal Inc., Ashland, Mass.*)

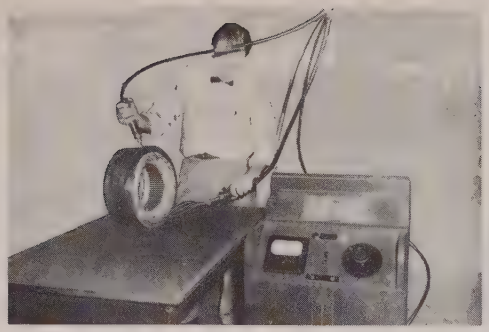
**Limiting Destruction.** Once a defective unit is detected, it is generally desirable that no further destruction take place. "Non-destructive" testing has become a phrase employed rather loosely in this connection. To state that the application of high voltage is non-destructive is a half truth. At best such testing will not do the insulation any good, and tends to be destructive in some degree. This is inherent in the application of high voltage to insulation, and has no relation to the type of test set. Destruction following failure can be limited, however, by providing the test set with any one of the following features:

*High leakage transformers* (Fig. 2). These employ a magnetic shunt across the secondary winding through an air gap. Under light loading of the secondary the shunt has little effect due to the low permeability of the air. However, at some value of volt-ampere output the magnetomotive force bridges the air to set up a magnetic short-circuit across the secondary, instantaneously limiting the maximum value of current which can be drawn from the secondary and reducing the output voltage to near zero. The transformer can withstand such conditions repeatedly without damage. Besides holding equipment damage to a minimum, the high leakage transformer also protects the operator. At present this type of construction has been limited to test sets under 500 va.

*Current-limiting resistors.* This is an older but still effective technique which will limit the maximum current flow of a test set of any construction. A minor drawback in their use is the necessity to use a transformer of a somewhat higher output voltage to compensate for the *IR* drop across the resistors and still permit adequate test voltage output. This may also affect the calibration of the voltmeter (depending on where the resistors are added in the circuit).

*Mechanical protective devices.* The sensitivity and speed of response of this type of protective device have been considerably improved, especially by use in conjunction with vacuum-tube amplifier circuits. On the larger sets this is generally the only protective device furnished. Being current-sensing in nature, however, they must be set high enough not to trip in the face of high capacitive currents, charging transients, etc. But a high setting may also introduce considerable time delay before tripping an actual fault current. If such devices were provided with an adjustable trip with reasonably wide range, and equally sensitive at all points, their major disadvantage would be eliminated.

**Designing for Production.** High-potential testing on a production line has several unique problems. The test must be performed quickly and accurately, often by unskilled personnel, without sacrificing any element of safety. Choosing the equipment is usually the smallest problem. A wide variety of small, reasonably priced a-c sets are available which are rugged, portable and provide means of detection which are suitable or can be made so for most applications. Other points to consider have already been mentioned, but on production testing particularly it is well to consider the possible savings through use of a test set also containing an audible alarm circuit. By freeing the operator from the need to watch the instrument panel, the testing rate can often be increased. In some instances the operator can be completely eliminated where the equipment is power conveyed past suitable terminals through which the test voltage can be applied automatically.



## . . . MOTORS

For testing induction-motor stator. hot lead is applied to windings and ground lead to stator frame. Test instrument is a mobile 0-3000 volt, 3-kva unit. In operation the voltage is preset at the instrument panel but is actually applied by a pushbutton on the prod of the hot lead. The pushbutton makes contact in a 12-volt control circuit to energize a circuit-closing relay in the tester proper. For convenience the test leads are suspended from the ceiling by a pulley and counterweight arrangement to hold them off the floor at all times and yet permit their being moved to other test sites in the area. (*Ilg Electric Ventilating Co., Chicago, Ill.*)

This semi-production test of fhp capacitor motors also utilizes a 3-kva mobile tester but with an automatic 1-sec timer to control the application of a preset value of voltage. To speed up test, leads from five different motors are tied in parallel and connected to the hot lead. Likewise the frames are all connected to the ground lead. Breakdown in this type of application can be detected by observation of the test specimens as well as fluctuation of the voltmeter pointer. For complete failure, a circuit breaker will trip to interrupt the test. (*Ilg Electric Ventilating Co., Chicago, Ill.*)

Where the production rate does not make testing time critical, standard models of available test sets can usually be used economically without modification. Where extreme safety is required, the test specimen can be housed in a non-conducting test cage equipped with suitable interlocks. When several types of electrical tests are to be made, it is sometimes advantageous to group all tests at one spot with the units wired through a master control panel to suitable test jigs. Proper instruction of the operator is of course mandatory.

A considerably more difficult situation exists where production rates are such that testing must be done as rapidly as possible. Here it is well to consider if the situation might not justify using units engineered all or in part for the specific application, if no standard unit appears completely suitable. In such a selection it will be economically advantageous to obtain the standard unit most generally applicable and modify it oneself, or on special order from the supplier.

Speed and safety are a difficult compromise. The diversity of applications makes specific suggestions difficult, but the following may be useful:

1. Be sure test set is adequately grounded.
2. If the test voltage is applied "hot," design method of application so that handling of leads is unnecessary.
3. If equipment under test has an input with plug, terminate HV lead of test set in suitable terminal box. Contact metal parts with ground lead and then apply voltage by inserting plug into box. This is reasonably safe to operator and yet rapid in use.
4. If operator must handle both leads, equip the leads with retractable tip prods, and if the voltage must be applied hot, either furnish foot switch control, or include a control circuit with one of the output leads so that the application of test voltage can be manually controlled by the operator while handling the leads.

For additional safety, use of a "push-to-test" switch is recommended wherever practical. This must be held down by the operator in order to apply the output voltage and will keep at least one hand out of trouble. For complete safety two such switches used in series would do very well. On test sets of increased capacity, a "zero-return" interlock is worth consideration. This is a device which will prevent the reapplication of the test voltage once the "push-to-test" button has been released or the circuit breaker tripped until the voltage regulating device is returned to the "zero" position. It thus renders important safety service by preventing unintentional energizing of the high voltage output.

**Testing Time *vs.* Voltage.** Most standards require that rated test voltage be applied to the specimen for 1 min. However, where speed of testing is essential, some standards permit an optional test at a rated test voltage 20 per cent higher applied for only 1 sec. Most insulation currently in use has a definite endurance characteristic under-applied high voltage a-c. Considering this. and the fact that no test sets currently on the market contain any sort of timing device, one is led to question how many tests are actually applied for 1 min., and also whether 120 per cent test voltage applied for 1 sec is really equal to rated test applied for 1 min. If a hi-pot test is not applied realistically in a manner capable of exposing a substandard insulation structure. then there is no point in applying such a test at all.

## *Typical Test Stations for . . .*

**. . . SYNCHROS**

At this special test station the high-potential test is performed in conjunction with insulation-resistance, circuit-continuity and other tests. The simple a-c tester on the top shelf terminates inside the master control unit, as does an insulation-resistance tester (not shown). The setup here illustrates the complementary use of both high-potential and insulation-resistance tests, as follows:

First the operator mounts five synchros in the test fixture shown at left, sets circuit-selector switch on the control unit to "stator-rotor," sets test selector to "megohm," "zeros" the insulation-resistance tester—then reads and records the insulation resistance. Next the operator switches test selector to the hi-pot position, adjusts the voltage to 900 volts and presses the "start" button to apply potential to dielectric circuit and initiate an automatic 1-min timer. During timed test period operator watches breakdown indicator lamp on the tester.

At end of cycle the time indicator light on the

### D-C High-Potential Testing

Increasing attention is being devoted to d-c testing by engineers, as evidenced by many AIEE papers on this subject. There are several basic reasons for renewed interest. The lack of real definition with a-c because of the masking effect of capacitive charging current has been pointed out. The main advantage of d-c, therefore, on quality control applications is the ability of the moving pointer on the ammeter to accurately spell out the true electrical behavior of the insulation.

To investigate the possible pros and cons of d-c testing, it will help to separate the items considered for testing into two groups, based on whether the time constants of the dielectric circuit are short or long. Figure 1 illustrates the theoretical current flow in an insulating structure when high voltage d-c is impressed on it. Initially the same three components of current are present as on a-c, i.e., capacitive charging current, dielectric absorption current, and true leakage resistance current. The subsequent action is quite different, however, as the first two components drop to zero after some finite time interval, leaving only true leakage current. This is true whether the voltage is applied hot or raised from zero, although the time interval will of course vary.

**Short Time Constants.** Assuming 1 min as the standard time of test, then our first group for consideration would be those items which under test would yield a true leakage current reading in less than a minute. For these items, d-c would appear to have great promise because insulation condition would be expressed quantitatively at a rated test voltage, not in such vague terms as "withstand without breakdown etc." It is true that some investigation may have to be made to establish suitable values of test voltage and duration of test so as to correlate with previous a-c experience. This should not be difficult and such data are now being accumulated by several manufacturers.

While d-c thus offers the positive advantage of definition, it must not be concluded that it is a panacea to solve all insulation testing problems. Balanced against its increased effectiveness will be probable higher cost of the d-c test set, as opposed to the small capacity a-c test set and its greater bulkiness due to the presence of additional rectifying and metering components. As the size of the equipment to be tested increases, the a-c test set rapidly becomes larger and more expensive than an equally effective d-c set, but it is hard to define where the shift in economics occurs. Considering commercially available test sets, it is the author's opinion that where an a-c test set of less than 500 va will suffice, it will be cheaper and smaller than a comparable d-c test set. An a-c set rated 500 to 1000 va will probably be cheaper but heavier. Above 1 kva, the a-c set will be both heavier and more expensive.

Another difficulty which may be encountered in varying degree, especially in rapid production testing, is the residual charge left on the equipment after a d-c test. For positive safety some method of discharging the equipment after test must be provided, either in the test set or in a separate jig or fixture. This can be an annoying problem as in some applications it will be necessary to short-circuit the tested item for a considerable time interval before safe handling can be assured. This would tend to slow down the rate of testing in order to provide protection to production personnel. Many small assemblies can actually be discharged almost instantaneously and so would present no problems, but it must be emphasized

control unit goes out; the operator reduces voltage to zero, switches back to the megohm test and again records the insulation resistance. For acceptance of the synchros, final insulation resistance must be above a certain value, with no indication observed on the breakdown light. Before-and-after insulation test is performed to catch any possibility of damage from the high-potential test.

The same tests are also performed for the stator-to-frame and rotor-to-frame dielectric circuits.

In a second series of tests each synchro is positioned on a mechanical jig, as shown, and the resistance of each winding is recorded as a circuit-continuity check. Finally with one winding energized the synchro is given a 1-min test, during which time the operator turns the rotor manually through two revolutions and watches for any fluctuation of primary current or tendency of the rotor to seek a preferred position. (*Arma Div., American Bosch Arma Corp., Garden City, N.Y.*)

that a potentially dangerous situation may be introduced and must be reckoned with.

In other respects small d-c and a-c test sets under 500 va appear to be about equally safe. The high-leakage transformer of Fig. 2 can also be used on the line side of a small d-c set for current limiting; its effectiveness here is generally increased by the higher internal impedance normal to a d-c set.

**Long Time Constants.** In considering the use of d-c on equipment where actual leakage current values cannot be obtained during the normal time of test, the situation becomes more complex. Dividing the applied voltage by the current value at the end of such a test period would yield an apparent resistance which could be much lower than the true resistance. This problem is also partially a function of the test voltage as at d-c voltages above 40 kv the corona current can be of considerable magnitude.

When the absolute value of the measured current cannot be used at the conclusion of the normal test period, several techniques can be followed:

1. Extend the test period until true leakage current can be read. This may require a time of application from 10 min to an hour, and its feasibility will depend strictly on the application. It would rarely be practical for a production setup except on extremely large equipment where time is secondary. But here the applied voltage can be raised gradually, and a highly capacitive piece of equipment can be tested by a d-c test set having a very small output—2.5 ma or less.

2. Retain the short test period and apply one or more empirical techniques of interpretation, such as: plotting and matching curves, determining polarization index, etc. However these techniques are beyond the scope of this article.

It might appear that the increased difficulty of interpreting current values would make d-c methods less advantageous on heavy equipment. Actually, quite the opposite is true. To date the greatest application for and progress in the use of d-c techniques has been with large rotating machines and wire and cable. For these applications, a-c test sets capable of applying a suitable high voltage to these items are much less mobile and substantially more expensive than an equally effective d-c set.

For this application d-c sets would appear to be safer than comparable a-c sets. Effective d-c testing can be done with output currents not exceeding 2.5-5 ma. The current output of equivalent a-c test sets, rated 5-25 kva, would be many times larger, and protective devices would be set proportionately higher. It is particularly important in this instance to re-emphasize that great care must be taken, after a high d-c voltage has been applied, to insure that all conducting surfaces and dielectrics which have been exposed to the high voltage field be solidly grounded afterwards and subsequently checked as necessary to eliminate any static charge from remaining or reappearing. Carelessness or ignorance here can have potentially lethal results, and testing should be done only with thoroughly trained personnel.

## Summary

1. The high potential dielectric test continues to be one of the most important methods for determining the quality and probable endurance of an insulating structure.

2. The success of such a test will depend on the method of test setup, capability of the test set and skill of the operator. Current standards provide a basis for evaluation but in many cases are too vague to be of much assistance.

3. From a theoretical standpoint the use of direct current provides a more definitive quality control test than does alternating current. Supplementing existing standards by including d-c tests where advantageous is a subject which should receive further consideration and investigation.*

For many applications a-c will continue to remain a cheaper, faster and more flexible method of testing than d-c. Some increase in definition can be obtained by proper utilization of design features provided in currently available test sets.

For heavy equipment d-c testing loses some of its definitive ability but gains overwhelming advantages in economy and mobility. O O O

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1. "High-Potential Dielectric Strength Testing." John T. Keefe, Electrical Manufacturing, May 1955, p. 112.
2. "Standard For Commercial Electric Cooking Appliances," Underwriters Laboratories, Inc. Report No. 197.
3. "The Insulation of Electrical Equipment," Chapter III, Willis Jackson, John Wiley & Sons, New York (1954).

*As reported in "ASA Revises Standard for Rotating Electrical Machinery," Electrical Manufacturing, June 1956, p. 150, American Standard C50.1—1955 now permits d-c dielectric tests for synchronous-machine windings rated 6000 volts and above.

**Read True Leakage Current**

Smaller, Less Costly Than Equivalent in A.C.

# D.C. HYPOTS

## FOR

## NON DESTRUCTIVE HIGH VOLTAGE DIELECTRIC STRENGTH TESTING

Associated Research Inc., has grown to be one of the leaders in the field of D.C. High Potential Testing. This method of testing, though still in its infancy, is rapidly growing in prestige as the non-destructive dielectric strength test for insulating materials. The HYPOT test sets listed below are specifically designed for dielectric testing on the production line, in plant maintenance departments, material laboratories, and for use in the field in the testing of wire and cable installations and their related equipment.

## PORTABLE BENCH TYPE

### MODEL 424

Input: 50-60 cycle, 115 V.A.C.
Output: 0-5000 V.D.C.
Current Range: 0-5-10-50-100 microamps

### MODEL 5002

Input: 50-60 cycle, 115 V.A.C.
Output: 0-5000 V.D.C.
Current Range: 0-5-10-50-100-250 microamps

### MODEL 5001

Input: 50-60 cycle, 220-230 V.A.C.
Output: 0-5000 V.D.C.
Current Range: 0-5-10-50-100 microamps

### MODEL 421

Input: 50-60 cycle, 115 V.A.C.
Output: 0-10,000 V.D.C.
Current Range: 0-500 microamps

### MODEL 5011

Input: 50-60 cycle, 115 V.A.C.
Output: 0-10,000 V.D.C.
Current Range: 0-100-500 microamps

### MODEL 5230

Input: 50-60 cycle, 115 V.A.C.
Output: 0-20,000 V.D.C.
Current Range: 0-50-250-2500 microamps

### MODEL 5250

Input: 50-60 cycle, 115 V.A.C.
Output: 0-30,000 V.D.C.
Current Range: 0-50-250-2500 microamps

Models 424, 5002 and 5001 terminate in 1 pair of 5 ft. high-voltage test leads which plug into front of panel. Positive lead has red rectractable tip prod, ground has Alligator clip. Models 421, 5011, 5250 and 5230 terminate in standoff insulator and ground stud on top of case.

## MOBILE TYPE

### MODEL 5265

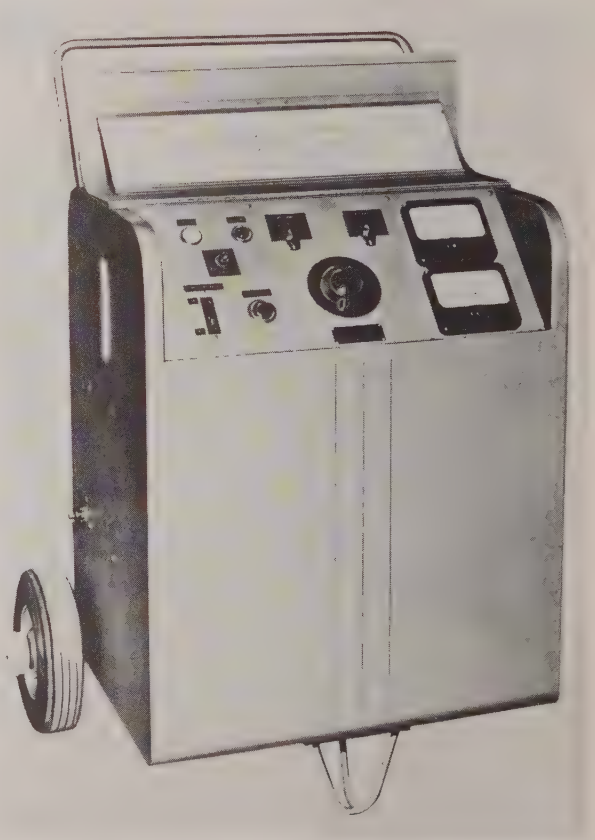
Input: 50-60 cycle, 115 V.A.C.
Output: 0-15-30-45 KV D.C.
Current Range: 0-50-250-2500 microamps

### MODEL 5275

Input: 50-60 cycle, 115 V.A.C.
Output: 0-70,000 KV D.C.
Current Range: 0-50-250-2500 microamps

### MODEL 5280

Input: 50-60 cycle, 115 V.A.C.
Output: 0-25-50-75 KV D.C.
Current Range: 0-50-250-2500 microamps



All Mobile Type D.C. HYPOTS are balanced for easy portability, and are equipped with a detachable push handle and cable reel. These units are ruggedly built to withstand field use and may be transported flat in the back of a car or station wagon. They are housed in a grey leathertone finish steel mobile type case mounted on 10" x 2.75" ball bearing semi-pneumatic puncture proof wheels. High voltage is obtained by use of the exclusive ARI AMPLIVOLT power unit; a rectifier-amplifier employing oil immersed long life selenium rectifiers.

**HYPOT**
Trade Mark Registered
**JUNIORS**

Speeds Dielectric Testing
Minimizes Errors

# SIMPLICITY

## MAKE SURE YOUR PRODUCTS ARE ELECTRICALLY SAFE

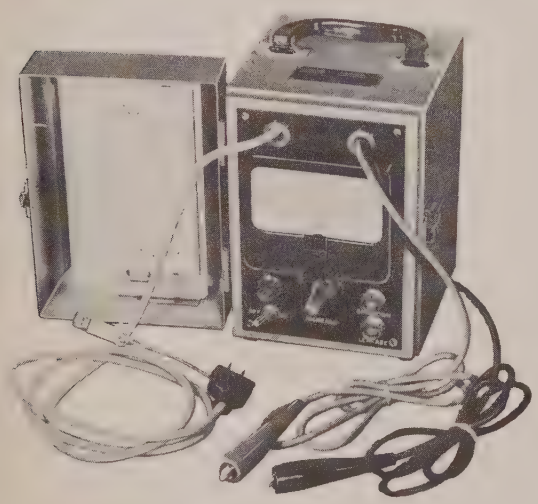
## *Test For Shorts, Leakage, Breakdown*

The Fabulous HYPOT Juniors Are Specifically Designed for Fast Accurate High Voltage Dielectric Testing

CURRENT LIMITED FOR NON DESTRUCTIVE TESTING

***LIGHT • COMPACT • PORTABLE • VIRTUALLY FOOL PROOF TO USE***

## VISUAL INDICATOR MODELS



### 400 SERIES

| MODEL | OUTPUT | CAP V.A. |
|---|---|---|
| 412 | 0-1500 | 50 |
| 411 | 0-2500 | 75 |
| 404 | 0-4000 | 100 |
| 405 | 0-5000 | 100 |
| 414 | 0-6000 | 140 |
| 422 | 0-10,000 | 230 |

### GENERAL SPECIFICATIONS

**Input:** 50-60 cycle, 115 V.A.C.
**Output:** Continuously variable output voltage from zero to maximum.

**Indicator Lights:** 3 Neon; "ON-OFF," leakage, breakdown, Leakage light set to glow at 0.5 MA. Standard (500 volts per MEG). Settings other than 0.5 MA, between 0.35 MA and 2.5 MA available on special order. Above models can be modified for settings between 0.1 MA and 0.35 MA or 2.5 MA and 10 MA when desired.

**Housing:** Grey Hammertone baked enamel finish, with removable cover. Compartment in cover for storage of test leads, line cord and instruction manual.

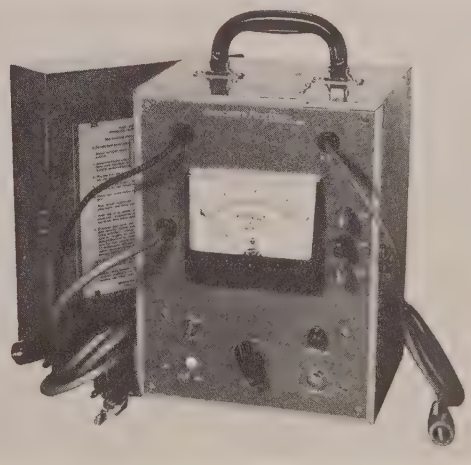
**Dimensions:** 6" x 9" x 8½"; Model 422, 8⅝" x 11½" x 10". All HYPOT Junior Models except Model 422 terminate in 1 pair of 5 ft. high-voltage test ieads, with terminals and rubber shielded Alligator clips. Model 422 terminates in a standoff insulator and ground stud.

## VISUAL AND SOUND INDICATOR MODELS

The Model 430 HYPOT series was specifically designed for production line testing applications, where it is undesirable or impractical for the operator to continuously watch the instrument for fault indication. A clearly audible alarm buzzer is heard in the event of excessive leakage current or failure of the insulation under test. The standard leakage circuit is set at 0.5 MA. Settings other than 0.5 MA, between 0.5 MA and 1 MA available on special order. Above models can be modified for settings between 0.3 MA and 0.5 MA or 1 MA and 10 MA when desired. These features make these HYPOTS extremely valuable tools for quality control testing of Motors, Components, Appliances, and other items requiring rapid and accurate high voltage insulation testing.

| MODEL | OUTPUT | CAP V.A. |
|---|---|---|
| 430 | 0-1500 | 50 |
| 431 | 0-2500 | 75 |
| 432 | 0-4000 | 100 |
| 433 | 0-6000 | 140 |

**Dimensions:** 8⅝" x 11½" x 10"



Other current limited A.C. HYPOTS are available for automation or control application.

There is an ARI HYPOT for every High Potential Testing Requirement.

*MANUFACTURERS OF THE ONE AND ONLY HYPOT*

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Bulletin 10-15.1

# Insulation

## *High Potential Dielectric Testing*

Editor's Note: The following are excerpts from the transcript of a technical seminar held on the West Coast to clarify some of the confusion and disagreement regarding dielectric strength testing. Members of the panel were: J. P. Dallas of Hughes Tool Co., Fellow of AIEE, and chairman of the Subcommittee on Dielectric Testing of Aircraft Equipment; H. N. Miller, vice president engineering, of Associated Research, Inc., one of the largest manufacturers of high potential dielectric strength testing equipment, member of AIEE, IRE, and ASTM; and C. L. Sidway of the Southern California Edison Co., member of AIEE and expert on the dielectric testing of large rotating machinery. The moderator was M. A. Brenner of Brenner-Fiedler and Associates, Inc.

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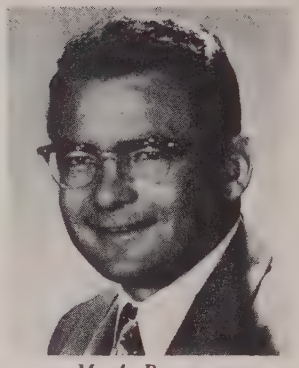
**Associated Research, Inc. . . . Chicago, U.S.A.**

*J. P. Dallas*

*C. L. Sidway*

*H. N. Miller*



*M. A. Brenner*

# *High Potential Dielectric Testing*

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*Brenner:* What do we mean by dielectric strength?

*Miller:* Dielectric strength is defined as the voltage rating at which electrical failure or breakdown occurs. It is commonly expressed in volts per mil, obtained by dividing the breakdown voltage by the thickness of insulation. The value is influenced by the method of application of voltage, frequency, wave shape, temperature, and surrounding medium.

*Brenner:* What about leakage current, test current, circuit current, and so forth?

*Sidway:* When you apply a direct potential to an insulated structure, the initial surge of current is known as the charging current. As time goes on the current drops exponentially, and another effect known as absorption current becomes predominant. If the potential is left on long enough the current eventually reduces to a steady value, known as the conduction current. In insulation testing, it is the conduction current in which we are primarily interested. When testing with alternating potential the charging component is extremely large compared to all the other components, so leakage current is relatively minor.

*Brenner:* Is breakdown an excessive steady current, arcing, or short circuit?

*Sidway:* Breakdown is usually described as a destructive discharge through the insulation. It is characterized by a disproportionately large change in the testing current; in other words, an avalanche. After breakdown failure occurs you usually cannot restore the voltage. For example, while slowly increasing the voltage you may find current increasing quite rapidly at a certain point, but you may have only reached the point where some of the voids in the insulation material have become ionized. If that is the case you can back down on the voltage and return to the same place as often as you wish. In a true breakdown you will not be able to raise the voltage to that point again.

*Dallas:* Insulation breakdown is also defined as a rupture of the insulation which results in the increase of leakage current at the specified test voltage.

*Brenner:* What is the relationship between insulation resistance testing and high potential testing?

*Dallas:* We use insulation resistance tests to tell us if insulation is contaminated or to discover things that are wrong with insulation that we can correct. Low insulation resistance may indicate what equipment is wet, dirty, deteriorated, etc. Though this would not necessarily result in breakdown it could result in short life, since current flow through insulation causes an electrolytic action which probably would hasten the ultimate failure. The minimum acceptable insulation resistance has been pretty well standardized as one megohm.

*Sidway:* The measurement of insulation resistance is affected by the voltage as well as the length of test time. The insulation resistance at the end of one minute, divided by the insulation resistance at the end of ten minutes is known as the polarization index. When the index is less than one half, you can be pretty sure that the insulation is dirty or contaminated, or otherwise defective. Generally, the

higher the polarization index the better the insulation. Temperature of the test also has a very pronounced effect on the measurement.

*Miller:* Insulation resistance testing is frequently used as a production line sorting test. For example, if 499 out of 500 amplifiers, toasters, or electric irons have a comparatively high insulation resistance while the 500th one has a low value, we throw out the 500th one because we know it is worse than the other 499. There also is a slight relationship between insulation resistance testing and breakdown strength testing (hi-pot testing), in that normally in a given piece of equipment the higher insulation resistance value indicates the ability to withstand higher voltages before excessive leakage current is drawn.

*Dallas:* These are things that are practically non-existent in any of the insulations that we have to use on aircraft and missile equipment. If you took samples of "Teflon," mica, and polyethylene materials and tried to compare values on the basis of insulation resistance you wouldn't get anywhere, especially since we are dealing with small areas of material that are harder to evaluate. These materials can yield figures of insulation resistance in the neighborhood of 100 to 200 megohms or even much higher.

*Brenner:* Is insulation resistance or high potential testing better for predicting equipment life, or do they complement each other?

*Miller:* In general, in tests made on high-production, low-priced types of equipment there is some correlation between insulation resistance and high potential testing. The hi-pot test usually called for is not a real breakdown test but merely the application of a relatively low (500 to 2000 volts) voltage to the equipment, and in one way or another you measure leakage current—whether by means of a leakage light, circuit breaker, or microammeter. You are actually interpreting the hi-pot test in terms of insulation resistance, because naturally, the higher the leakage current the lower the insulation resistance. The equipment specifications will frequently tie you down by calling for one or the other of the tests.

*Brenner:* For quality control purposes can you get better results by first running an insulation resistance test, then a hi-pot test, then another insulation resistance test, and then comparing the values of the two insulation resistance tests?

*Sidway:* In testing large machinery we always make an insulation resistance test first, simply to determine if the system is suitable for applying a high potential. The only way we can find out if the system has a specific dielectric strength is to apply the high voltage. If there is no breakdown we are reassured that barring accident or change in operating conditions, the equipment will run until the next time we test it.

*Dallas:* When a switch is opened or closed the transient voltages developed rise to an exceedingly high value compared to the circuit voltage, and it is one of the main reasons for making hi-pot tests. The purpose of the high potential test is to detect flaws in the insulation, and since most insulations of even a few thousandths of an inch thickness will withstand several thousand volts without being unduly stressed, a test voltage of around a thousand volts or so will not harm healthy insulation.

*Sidway:* If you make an insulation resistance measurement and find that it is exceedingly low you certainly should not try to apply a high potential test. On the other hand, if the insulation resistance is very high it still does not give any assurance that the structure will pass a high potential test. Since leakage current flows pretty generally over the surface of the insulation as well as through the insulation itself, the effect of a small pinhole which could cause a voltage breakdown may be rather slight in the measurement of the insulation resistance. We have found after making numerous tests that the difference in insulation resistance before and after hi-potting is not much of a criterion.

*Question from the Floor:* Can you use a hi-pot test to make an insulation resistance test?

*Miller:* If you are making a high potential test using d-c you can read the leakage current directly on the milliammeter, and at any given instant you can calculate the insulation resistance by using Ohm's Law: $R = \frac{E}{I}$.

Most insulation resistance tests are specified at 500 volts, so all you have to do is raise your voltage to that value and divide the 500 volts by the leakage current to get your insulation resistance. Then of course you can continue raising the voltage until you break the insulation down.

*Sidway:* The value you get in measuring insulation resistance depends on the test voltage. In one example the insulation resistance measured at 10,000 volts was 3800 megohms; at 15,000 volts it was 2700 megohms; at 20,000 volts it dropped to 2000 megohms; and at 25,000 volts it was down to 1500 megohms. It is quite feasible to calculate insulation resistance while you are making a d-c hi-pot test, and if you do it properly you can get almost any value you choose.

*Dallas:* For about 75 years the electrical industry has used the figure of one megohm for satisfactory insulation resistance. It is pretty much a rule of thumb. The reason some of the missile people call for high impedances is partially due to inexperience or as a result of less than optimum design.

*Brenner:* The commonly accepted test voltage in a-c high potential test is twice rated voltage plus 1000 volts. Is this still valid?

*Dallas:* In the early days of electrical design it was decided that a reasonable surge for switching transients was about 1000 volts. Then if you added twice the line voltage you had a good basis for a high potential test. I believe that is as true today as it was 75 years ago.

*Sidway:* As soon as a machine is put into service the insulation starts to degrade because of the effects of temperature, time, moisture, vibration, etc. The machines must still withstand the effect of surges, lightning and other high potentials. I concur that the figure is still valid today.

*Brenner:* In the missile field—especially where we operate with very low voltages of 28 volts d-c, using small components, fine wire, etc.—won't

this application of twice rated voltage plus one thousand cause damage to the equipment? Shouldn't we therefore lower the value?

*Dallas:* It is a recommendation of the AIEE subcommittee on Aircraft Equipment, Electrical Insulation, that not less than 1500 volts or 1000 volts plus twice line voltage be applied to all equipment. This is to find flaws in the equipment and has nothing to do with wire or component sizes. To put a voltage across a .003″ air gap takes about 1200 volts, but the 1200 volts won't stress .003″ thick "Mylar" at all. It would take 3000 or 4000 volts per .001″. So whether the equipment operates on 2 volts or 1000 volts, the problem remains of finding the flaws in the primary insulation and that requires a sufficiently high test voltage.

*Brenner:* Can you determine anything from a high potential test using only 100 or 200 volts?

*Dallas:* You can learn absolutely nothing from a high potential test if the voltage isn't high enough to show flaws in the minimum thickness of insulation.

*Brenner:* Can we conduct a high potential test that is not damaging but will still yield some valuable information? In other words, does a high potential test have to be destructive to achieve its purpose?

*Sidway:* The purpose of the high potential test is to find faults in the insulation. The simplest test is the breakdown test, since it gives you the most straightforward answer. In a design test you want to find what value of voltage the insulation system will withstand, so you test it until it fails; then you know it will withstand a little less than the voltage you have applied. It has been our experience that test voltages of about 70 or 75% of the actual breakdown value will not even begin to injure the material during the test. Therefore, the design value of the insulation strength should be well above the value you expect to use in production testing. The length of time of application of the voltage is very important because of an insulation characteristic we will call voltage endurance. It is somewhat akin to the relationship of fatigue tests on metal and their tensile strength. The tensile strength is always higher than fatigue strength, so in our insulation system the short time strength is always higher than the long time strength. Results of many tests indicate that the rate of degradation during d-c high potential testing is considerably less than in a-c tests.

*Brenner:* If you are conducting an a-c test on a production line and one item has considerably more leakage current than other similar items, would you consider that a defective part or must you actually have a rupture or avalanche of current?

*Dallas:* It would depend entirely on the values found. The fact that there is a difference in the area below one megohm would be of special significance. You can just breathe on some surfaces, however, and drop the insulation resistance from 100 megohms to 20 megohms. In general, the high values are unstable; so if there is a difference above one megohm, don't pay any attention to it.

*Sidway:* I concur with Mr. Dallas that a change is significant, although I don't think the values you get are of any importance. If you are running tests on identical parts under controlled conditions and suddenly find a part that is either very high or very low, you know there is something different and you better find out why.

*Brenner:* If an a-c test is specified, can a d-c test also be used? If it can be used, how do we determine the d-c equivalent of the specified a-c voltage?

*Dallas:* For aircraft and missile equipment the d-c voltage should probably be about 1.7 x rms voltage. There is no fixed rule to apply, however, and you can find values ranging from 1.4 x rms to 2.3 x rms voltage. In our laboratory we usually use the value of 1.6 x rms voltage.

*Sidway:* In general, when we talk about a double voltage plus 1000 volts test we are referring to the one minute hold test. In other words, the voltage is brought up to the predetermined value and held for one minute. If you compare the d-c breakdown voltage to the one minute hold value, or compare it to rapid rise value, you will get a different ratio. The d-c test will not stress the material in the same way that the a-c does. Since most materials are not entirely homogeneous you have several dielectrics in series. With a-c, the voltage is divided across the structure in proportion to the dielectric constant of the material; while with d-c, the voltage is divided in proportion to the resistance of the material. The various sections of the material are therefore stressed differently with d-c than with a-c, since the dielectric constant does not necessarily correlate with the insulation resistance. Experience shows that imperfections, such as an actual air path, hole, or crack, will yield similar results with the 1.4 ratio between d-c and a-c. Cable manufacturers' specifications usually call for a ratio of 3 to 1, however. We have found over the years that using a direct voltage of 1.8 x a-c value has given us good results. The generally accepted rule of thumb, however, is that you should use a value of 1.6 to 1.7 times the prescribed a-c voltage.

*Miller:* While I agree fully with Mr. Sidway that the 1.6 to 1.7 times the a-c value is a logical choice, some specifications call for voltages of 1.1 x rms value, which is about the lowest correlation you might come across. An often specified value of 1.6 x a-c voltage for new equipment frequently is dropped to 1.1 x a-c value for older machines.

*Dallas:* Equipment which passes a d-c test may subsequently fail with an a-c test, since with a-c you are causing electrostatic motion of twice the applied frequency on any thin insulation sections which can move. This causes a very high stress which you don't get when using d-c. Although we frequently use d-c in aircraft missile testing, especially in large cable where it is much more convenient, we also use it with the full recognition that we have to use a higher voltage than the figures mentioned here.

*Sidway:* I might add that in a-c testing there is also a dielectric heating effect that in itself may lead to breakdown. A cyst or air inclusion in the insulation system may also be more readily found with an a-c breakdown test, since the distribution of voltage may cause internal corona in the void.

*Brenner:* Why would we want to use

d-c rather than a-c, which is the relatively established standard for high potential testing?

*Miller:* We recommend d-c testing wherever possible because it gives more of a qualitative rather than a go-no-go method of indication. With a-c testing you run the voltage up to a prescribed value and equipment either passes or doesn't pass the test. Failure is usually indicated by means of a circuit breaker, neon light, or any of the many other ways you can indicate leakage current or breakdown current. With the d-c test, as you gradually raise the voltage, you meter the leakage current and as long as the leakage current is climbing roughly at the same rate as the voltage, you know that the insulation is holding up. In many cases you can anticipate breakdown by observing the sudden increase in the slope of the current vs. voltage curve (called a knee). By stopping the test voltage short of the avalanche current that occurs with breakdown you can avoid damaging the equipment, but still get a good indication of the voltage at which breakdown will occur. Furthermore, with d-c testing, since you are metering the current, you can determine the leakage at any particular voltage; while with a-c testing the only indication you have is when the leakage exceeds the preset amount that triggers the leakage alarm.

*Dallas:* If you have a defect in the insulation, there is no reason to worry about destructiveness of the high potential test designed to detect flaws. Even if you could approach the flaw and stop you wouldn't actually want to stop, so I don't know why people testing aircraft equipment would want a so-called non-destructive test. As a matter of fact, when you are looking for a fault in the equipment you want to burn it in so you can find the exact spot where the insulation failed; therefore, a go-no-go test is exactly what you want.

*Miller:* The equipment being tested is the prime factor. The manufacturers of washing machines, radios, etc., wouldn't concur with you. I'm sure Mr. Sidway wouldn't want to destroy one of his 50,000 kva generators because of a potential flaw. The matter of being able to approach the breakdown point without destroying equipment leaves it up to the test engineer to determine the most appropriate time for taking the equipment out of service for repairs.

*Sidway:* In plotting leakage current against voltage you have to be careful, because you can get a false indication or a false interpretation of the knee in the curve. In one test we ran we suddenly got a knee at about 28,000 volts, and further investigation indicated the rapid rise of leakage current was due to corona from the test lead. As soon as the lead was replaced with a heavy shielded wire we were able to run up to 40,000 volts. In other cases where machines suddenly broke down without any sign of the knee, we found the nature of the fault was frequently a hole in the insulation. The voltage vs. current curve was smooth until the corona voltage of the hole was reached, then the sudden ionization of the air gave an immediate breakdown. In other words, you can sometimes predetermine the point at which failure will occur, but not always.

*Dallas:* With some of the newer insulations, that "not always" can be reworded as "very seldom." In the missile field we usually get breakdowns simultaneously with any large increase of current flow, whether it be a-c or d-c. It is almost impossible to detect breakdown just before it occurs.

*Brenner:* What is the principal advantage of using direct current?

*Miller:* In addition to the technical advantages we previously mentioned, there are sound economic reasons. I can give you a few examples to pinpoint this. On smaller equipment, that is, around 1000 to 5000 volts, d-c test equipment is a little more expensive than a-c equipment, primarily because of the more complicated metering circuits usually included. As we increase the voltage the cost of the a-c equipment goes up much faster than the d-c equipment, so that by the time we reach the 30,000 volt range the a-c equipment gets more expensive than d-c. By the time we get to about 100,000 volts or so, a-c equipment costs several times that of d-c and weighs several times as much. The a-c machine has to supply the capacitance current which gets to be considerable in the large units, while the d-c machine has to supply only the leakage current, with a little left over for stray currents.

*Brenner:* What are the differences in technique between a-c and d-c testing? How would you perform the test? Is the indication of failure the same in both cases?

*Miller:* Here again the type of equipment under consideration dictates the answer. The bulk of the miscellaneous low priced equipment such as household appliances, general consumer goods, etc., is almost universally tested with a-c; that is, low voltage a-c testing with a preset leakage light setting that will indicate leakage of more than ½ milliamp. With equipment that has higher capacitance, the leakage light setting is arbitrarily raised to a point where it will not glow for good units but will glow for poor units. The test voltage usually required by Underwriters or NEMA is twice rated voltage plus 1000 volts. Voltage is momentarily applied between live and grounded sections of the appliance. If the leakage light glows the unit is thrown aside for repair, and if it doesn't glow the unit is good and is passed. That's the way it is done in one field. Where specifications such as those set up by ASTM are required, a more rigorous procedure is followed. ASTM doesn't seem to recognize d-c testing, so any reference to an ASTM specification automatically means a-c. ASTM specs are also go-no-go type tests. In the rate-of-rise test, the voltage is raised at a preset speed which may vary from 500 volts to about 3000 volts a second, depending upon the material and specification. The test is made by raising the voltage either to a predetermined value or until the specimen breaks down. In the step-by-step method the voltage is raised in discrete steps, each value being held for a fixed interval of anywhere from a few seconds up to a minute or more, depending upon the specification. Here again the voltage is raised either to the predetermined value or until the specimen breaks down. Another type of a-c test is in the nature of

an endurance test where the voltage is held at a fixed value for an interval from a minute in some applications to a day in others. The voltage is then raised by fixed amounts and the test continued. In d-c testing the voltage is also raised by discrete amounts. At each step, sufficient length of time is allowed for the leakage current to settle down and then the voltage and the current are read and plotted. The voltage is raised up to the limits set by the specification or manufacturer or until it is anticipated that material is about to break down or even until it actually does break down, depending upon the purpose of the test. A second but not quite so common test is that of applying a preset voltage and if the equipment shows a leakage current of less than the predetermined value, the equipment is accepted; while if it is higher than that value, it is not accepted. There are about as many detailed methods of testing as there are manufacturers and testing agencies.

*Brenner:* What is the effect of sudden vs. gradual application of voltage?

*Sidway:* The rate of application affects the value you get. Most of the standards for machine testing call for application of twice rated voltage plus 1000 volts for one minute. Normally you would bring the voltage up at the rate of about 1000 to 3000 volts a minute to at least 60% of the final voltage, then raise it as quickly as you can to the final voltage. The important thing to remember is that most of the destructiveness of an a-c test occurs after the voltage has reached 70 to 75% of the breakdown strength. All the other methods Mr. Miller mentioned are used in design work or development work in developing these voltage endurance tests. When the voltage is applied to a specimen in a few microseconds we have what is called an impulse test. The breakdown strength in that type of test is quite high. As the length of time of application increases, the breakdown strength lowers.

*Dallas:* It is usually desirable to apply the test voltage slowly to the extent that an indication of breakdown will be an immediate signal to the operator to reduce the test voltage. The test voltage may also be applied and removed instantly, although this is a rather controversial subject. We've never been able to find evidence of any surge appearing across the equipment if we applied the voltage from the source directly to the equipment.

*Miller:* We have two objections to applying the high voltage suddenly. First is that of operator safety, since many times unskilled help handle the high potential test leads. This can often be adequately safeguarded so that it becomes a minor factor. The second objection is that of potential damage to the test equipment itself. The equipment being tested usually is slightly capacitive, so that at the initial application of high voltage it represents a short circuit. In the instant prior to making contact between the high potential lead and the subject, a large arc can be drawn, depending of course upon the speed of application of the test lead, the preset voltage, and the current capabilities of the machine. This arc sends out a strong RF surge through the test equipment, and a considerable amount of research was expended to develop adequate means of protecting the meter diodes and other sections. This RF surge usually results in a much higher voltage than that of the test being run. In addition, the high frequency often can burn out parts of the equipment where a 60 cycle surge will not have any effect.

*Brenner:* What about the effect of successive applications of high voltage? What is the effect on the output failure point of the specimen when several hi-pot tests are made in the course of its manufacture, inspection, and maintenance? If there is an effect, is there any difference in using a-c or d-c?

*Dallas:* Since we are extremely weight conscious in the missile field, we have to design equipment using the absolute minimum insulation to do the job. If you plot the length of time the material will withstand a given voltage against the voltage, you will find that the breakdown time increases rapidly with a decrease in voltage. In fact, when you get beyond the one hour breakdown point, a very small percent of decrease in test voltage will increase the life of the insulation a very long time. We therefore pick insulation that can withstand 1500 volts for an hour, so we are able to apply a large number of tests at that voltage without seriously deteriorating the insulation in the least during the test process. For example, 10 one minute tests will reduce the life of the insulation a very small amount. The AIEE test code which calls for a 1500 volt high potential test also calls for a 20% reduction in the high potential test voltage on repeated tests, or for service and maintenance tests. Because of the shape of the withstand time vs. voltage curve, if you go beyond the one hour point you actually can withstand hundreds of hours of testing at a 20% reduction of voltage. That means the number of re-tests that can be conducted is almost unlimited.

*Sidway:* I agree with Mr. Dallas but further point out that equipment manufacturers take this into account. For example, during the manufacture of a machine the wound coils are given a one minute, 60 cycle test at 135% of the final test voltage (double operating voltage plus one thousand volts). After the coils are placed in the slots they are again tested by rapidly raising the voltage to the test value and reducing it quickly. This test is made at 126%. Then, after the core and connections are taped and the winding is brought out, it will be given another rapid rise test of 116% of the double plus a thousand volts. When the winding is finally completed and reaches the test floor, it is given a one minute test at the double plus 1000 voltage. So you see in the fabrication of ordinary power equipment there is a degrading of test voltages from the time the coils are made until we make the final test. Insulation systems are so designed that none of these tests encroach on the integrity of the insulation. We have applied the one minute test repeatedly, hundreds of times, without any measurable change of quality of insulation.

*Brenner:* Is there anything that specifies decreasing the voltage rating in successive tests to prevent damage to insulation?

*Dallas:* We believe a manufacturer should do his testing at a voltage higher than the 1500 volts recommended by the aircraft industry by an amount sufficient to take care of the differences in tolerances between the meters in the manufacturers' test equipment and the customers' test equipment, line voltage surges, etc. He should add at least 15% to the test voltages. In other words, by having the manufacturer test the equipment at 1800 to 2000 volts while it is going through assembly the customer can safely apply 1500 volts test.

*Brenner:* Another subject tied in with testing is the effect of time on the application of voltage. In other words, why should you apply the voltage for one minute rather than one second . . . or even an hour?

*Sidway:* The voltage endurance periods of insulation vary with the material. You must first establish a knowledge of the dielectric properties of the material you're working with. Once you know the endurance characteristics which tell you how the dielectric stress varies as a function of time, you are in a position to fix the test values. Your system in the first place must be designed to have adequate strength; then if you test at 75% of this maximum strength, repetitive testing will not cause any damage. In other words, fears of making tests in fairly well designed systems are groundless. You cannot build a mechanically sound insulation system in which insulation is so thin that you can use a test voltage of less than 1500 volts with any assurance. Many other things hurt the system more.

*Brenner:* When making an endurance test, do you get the same effect if you apply the 1500 volt test potential for one minute 10 times as you would if you applied the voltage one time for 10 minutes?

*Sidway:* There are three main causes of insulation breakdown. Failure may occur if the current flowing through the insulation is so high the dielectric losses heat the material. Another type of failure is caused by internal ionization. The third type of failure is caused by actual electronic disintegration, as in the case of impulse testing. Generally, thermal failure occurs when the copper is run hot, which in turn heats the insulation. It is seldom caused by leakage current heating the insulation. Most of the failures we have to deal with are caused by ionic disintegration, and there it is possible to have accumulative injury if the test voltages are high enough. However, we have stressed that you should do your testing at voltages well below the predetermined ultimate strength so you will not get into the thermal or ionic disintegration range. When that is the case, it doesn't make any difference whether you apply a one minute test with rest periods 15 times or apply the same test for 15 minutes without rest periods. It is only when you are working with a value of leakage current sufficient to cause heat that cannot be radiated that the rest period becomes sensible. In many equipments we have made repetitive tests with the rest periods and have made other tests leaving the voltage on the machine for weeks at a time, and have found no changes. It is necessary to understand the area you are working in and what the nature of the destruction is, and then you can judge whether repetition is going to give you accumulative trouble.

*Brenner:* What is corona? What is its effect? And why do you have to worry about it when you are testing?

*Sidway:* There are at least two kinds of corona effects. First is the superficial corona we get due to the dielectric stresses on the surface of the equipment being tested. There, you often can see long streamers or other visible display. While this external corona does no harm, it plays havoc with any current measurements you are trying to make, because the corona currents are usually very high. The other type of corona that we do have to worry about is the corona that forms within the equipment. This corona can disintegrate insulation and exhibits an accumulative effect. Corona can be present at surprisingly low voltages. You can have serious corona problems at 4000 volts, and I've known cases of corona trouble in motors operating as low as 480 volts. Some materials are much more susceptible to corona than others. "Mylar" film in some forms is particularly sensitive.

*Dallas:* Corona has a strong effect on missile equipment. You can sometimes lose 20% of the effectiveness of some insulating materials after a five second exposure to corona. Essentially, corona is ionization of the air due to the high voltage, and when the air disassociates you get a bombardment of the insulation material. This doesn't affect mica too much although it will eventually erode it, but it erodes "Teflon" and "Mylar" materials very rapidly. You can get serious destruction of insulation due to field concentrations even in those cases where we can't measure the presence of corona by orthodox means.

*Sidway:* There is a definition of corona that describes it as a luminous discharge due to ionization of the gas around the conductor which exists when the voltage range exceeds a certain critical level. This level is the corona starting voltage and it becomes lower and lower as the atmospheric pressure decreases, so that a machine that is well designed at ground level may not work at all at higher elevations.

*Brenner:* In specifying high potential tests it is important to indicate the voltage, the rate of rise of that voltage, how long the voltage should be applied, and most important, what constitutes failure. Regarding failure, is there a maximum amount of allowable leakage current, or should you wait until the circuit breaker pops, should you look for arcing, or just what determines whether or not the product is acceptable?

*Dallas:* In testing a specific item I think either a definite leakage value or circuit breaker setting should be specified.

*Sidway:* The frequency of the test voltage should also be specified, since a test made at 60 cycles will give you a higher breakdown value than one made at one kilocycle. We only consider failures that are real breakdowns; that is, where we get a very high change in current flow and where we cannot raise the voltage again to the previous value. The circuit breaker should be set high enough so you actually puncture the insulation before the breaker goes.

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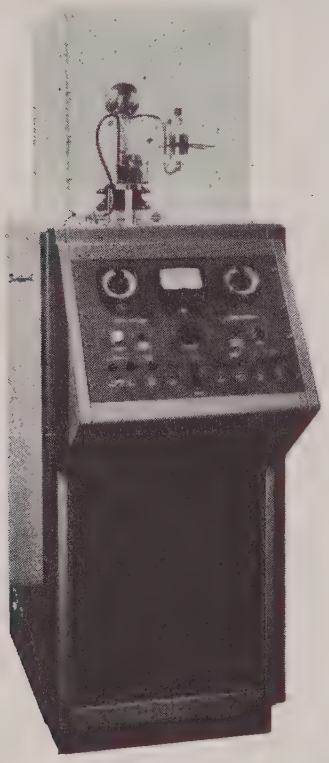
# Headquarters for INSULATION TESTING

NEW INSTRUMENTS from Associated Research, Inc. .. Chicago, Ill.



Model 4510

## HYPOT® Model 4510 Materials Tester

- **Motor Driven Variable Rate of Rise**
- **Timer for Dwell Period on Test Sample**
- **Kilovoltmeter Has Electronic Memory of Potential at Failure**

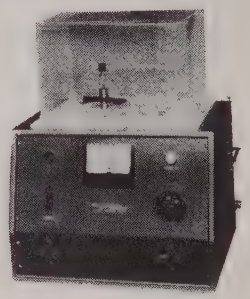
Provides widest range of testing for solid and liquid electrical insulations to ASTM and Federal standards.

Output 0-50 kv a-c at 2 kva with rate of rise adjustable from 300 to 3000 volts per sec. Dwell for test voltage on sample is controlled by an electronic timer. Electronic memory circuit indicates potential at which insulation breakdown occurred. Housed in caster-mounted console cabinet. Safety provisions include interlocked test cage at top with full view of the sample.

**Model 4712 Oil and Material Tester**

This 60 kv a-c at 2 kva oil and materials tester is complete with test cage, oil cup, and U.S., English and German standard electrodes. A dual sensitivity circuit breaker provides flexibility for measurements at low voltages. Descriptive bulletin is available.

## Insulating Materials Tester HYPOT® Model 4501



Designed to meet the dielectric strength testing requirements of ASTM Specification D-149. Output 0-35 kv a-c at 2 kva for testing of solid and liquid electrical insulations.

Output continuously variable from zero to maximum. Fast-acting magnetic circuit breaker trips at the instant test sample breaks down. Output terminates in two jacks at the center of the lucite cabinet top to accept the complete line of ARI materials testing fixtures.

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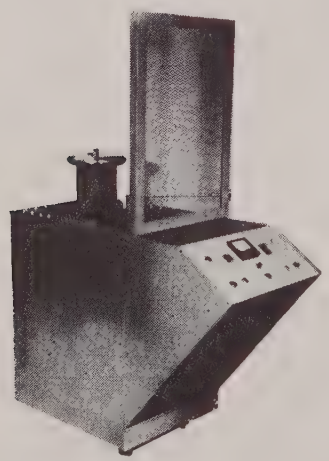

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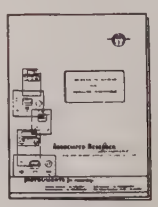

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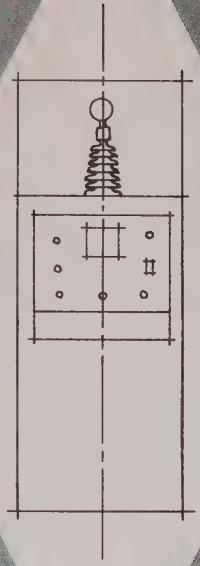

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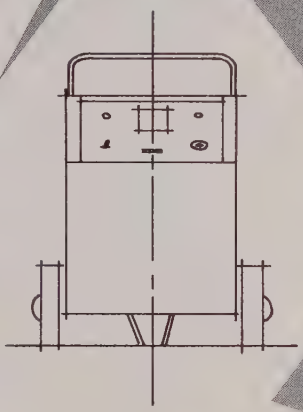

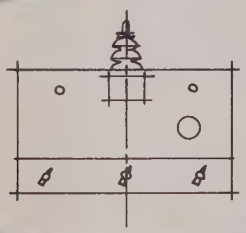

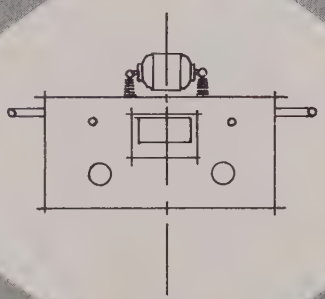

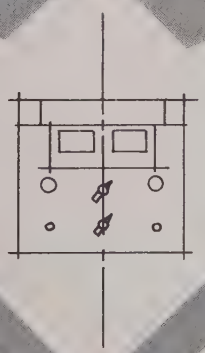

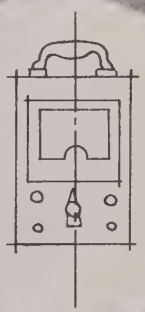


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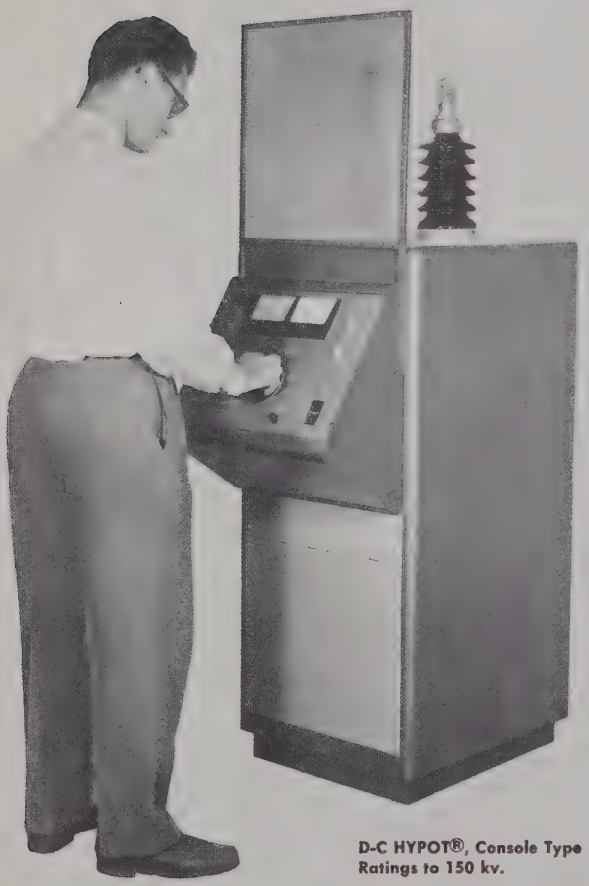

D-C HYPOT®, Console Type
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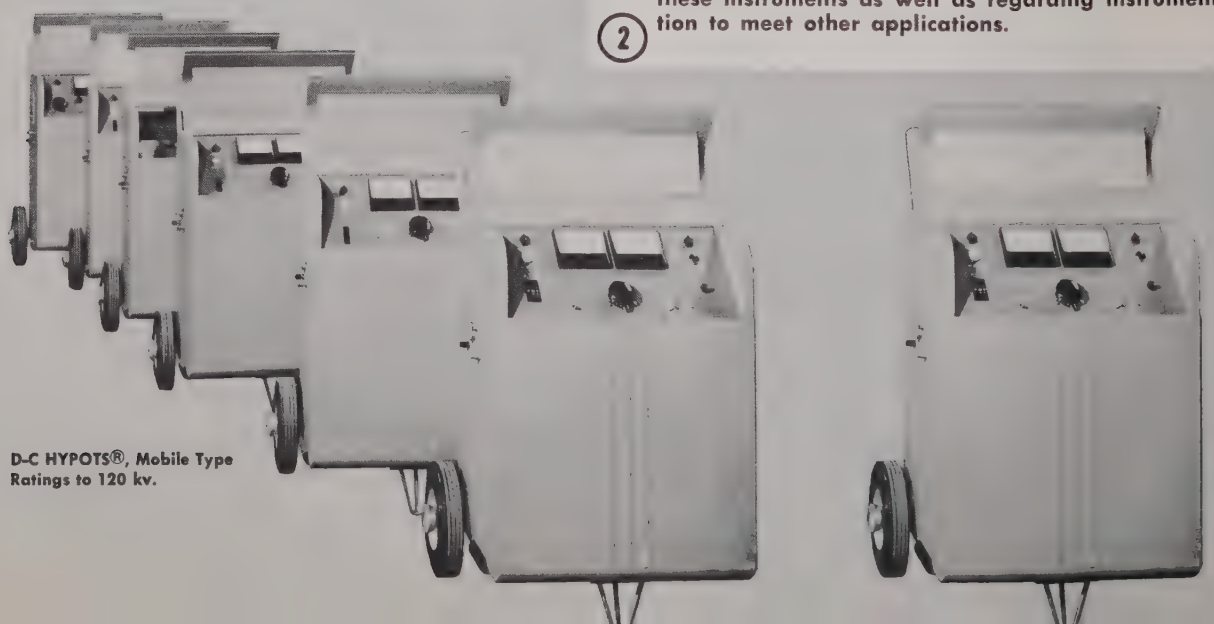

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A full range of instrumentation for non-destructive breakdown tests is offered. Pages 4, 5, 6 and 7 of this catalog describe each basic series. Page 11 gives data on automated systems for dielectric strength testing. Page 3 refers to instrumentation combining dielectric strength testing with tests that are frequently made concurrently.

Our experience as one of the largest and best equipped producers of heavy duty dielectric test sets has shown the need for wide variations in the facilities to be embodied in the individual test set.

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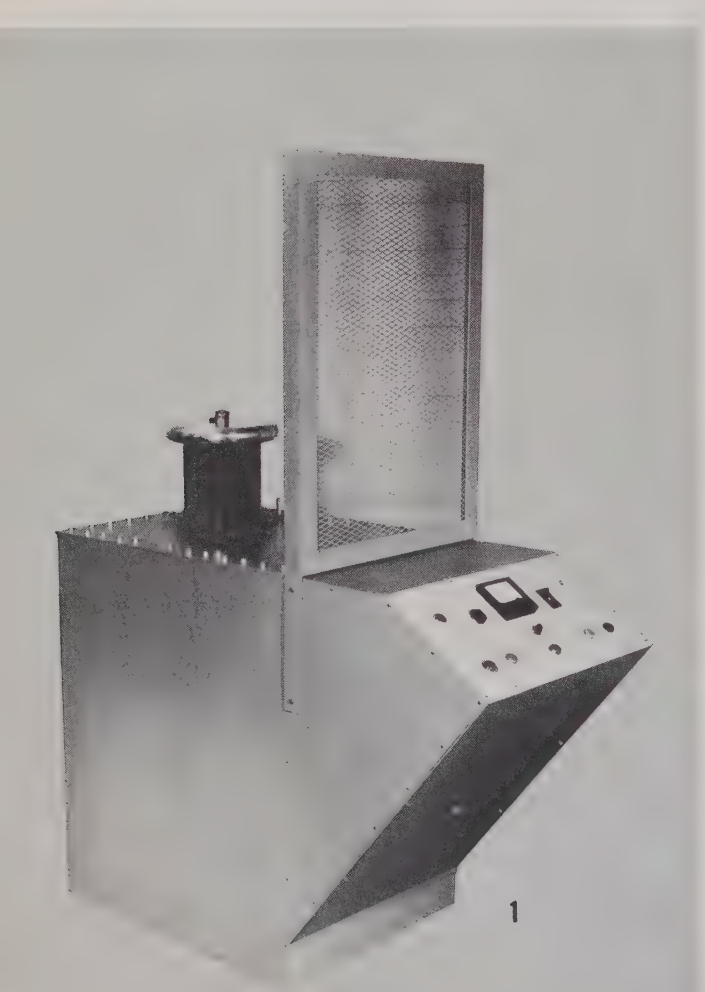

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These test sets are available with ratings of 150 kv to 250 kv, and maximum current outputs of 2, 5, 10 or 25 ma. Operating controls may be located on the main cabinet similar to Fig. 1, or in a separate bench cabinet. Output is through a heavy-duty, oil-filled, corona-free bushing.

Standard features include: 4½" Kv meter connected directly across high voltage output; 4½" electronically protected multiple range current meter; metered return and bypass guard circuits to measure load (leakage) current or bypass (guard) current; long-life selenium rectifiers; fast-acting magnetic circuit breaker for protection of high voltage circuits and external load; primary circuit protected by thermal overload breaker. Additional safety provisions include zero-return interlock, connector for remote interlock, cabinet and panel at ground potential, grounded screen between operator and high voltage bushing.

Optional features include: Automatic rate of voltage rise, adjustable high limit shut off controlled by voltage or current; corona pick-up and detector; kilovoltmeter memory circuit to retain reading of breakdown voltage; multiple output voltage measuring ranges; vacuum tube microammeter with ranges as low as 2 microamperes full scale. Additional features are described in special bulletin.

## Heavy Duty A-C HYPOTS® . . 150 KV, 10 KVA

For testing large rotating machinery, heavy equipment, line materials, cables, insulating liquids and materials . . . available with ratings to 150 kv at 10 kva and higher. Input; 220 v, single phase. Output continuously variable from zero to maximum. Terminates in a corona-free, oil-filled bushing.

Standard features include: Rectifier type 4½" kilovoltmeter directly across the high voltage output. Housed in heavy steel, caster-mounted cabinet (Fig. 1). Cabinet and panel are at ground potential. Grounded safety screen is between the high voltage bushing and the operator. Additional safety features include: Zero return interlock; connector for remote interlock; fast acting magnetic breaker in output to protect high voltage circuits and load; primary circuits protected by thermal overload breaker.

Optional features include: Multiple kilovoltmeter ranges; single or multiple range output current meter; dual range or adjustable secondary overload circuit breaker; adjustable high limit shut off for voltage or current; kilovoltmeter memory circuit to maintain reading of breakdown voltage; automatic control for rate of rise with pre-set dwell; corona pick-up and detector; control section in separate bench type cabinet; and others detailed in special bulletin.

**Automatic Rate of Rise Control** . . . Most of the A-C and D-C HYPOT® models may be equipped with automatic control to raise or lower the output voltage at a predetermined rate as required by many test specifications. Single speed, multiple speed or continuously adjustable options are available. Timer to permit presetting dwell period may also be included. Full description will be obtained by requesting bulletin.

# HYPOTS®

## Console A-C HYPOTS® . . 75 KV, 5 KVA

Models have outputs continuously variable from 0 to 30 kv, on up to 75 kv, at ratings of 1, 2, or 5 kva. Housed in caster-mounted steel cabinets finished in baked grey hammertone, with aluminum control panels in blue hammertone. Dimensions: 21¼" wide, 25½" deep plus 10" for control panel, 51" high plus 20" to top of protection screen. Weights from 600 to 1100 pounds. (Fig. 2). Standard and optional features include those listed for the "Heavy Duty A-C HYPOTS®" on the preceding page.

## Console D-C HYPOTS® . . to 150 KV, 10 MA

For non-destructive testing of insulating materials, cables, transformers, switchgear, motors and generators. Outputs continuously variable from 0 to 100 kv through 150 kv, with standard current ratings of 2.5, 5, and 10 ma at maximum voltage. Lower voltage and/or higher current units are available.

The caster-mounted console cabinets are similar to those of the "Console A-C HYPOTS®" described above. Weights from 650 to 850 pounds. Standard and optional features include those listed for the "Very High Voltage D-C HYPOTS®" on the preceding page.

## Mobile A-C HYPOTS® . . to 30 KV, 10 KVA

Mobile A-C HYPOTS® for testing large rotating machinery, line materials, short lengths of cable, and insulating materials.

Available with outputs continuously variable from 0 to 5, 10 and 20 kv at ratings of 1, 2, 5 or 10 kva. 30-kv models can be supplied with ratings of 1, 2, and 5 kva. Input is 115 v for 1- and 2-kva models, and 220 v for 5- and 10-kva models.

Standard features include: Rectifier type 4½" kilovoltmeter directly across high voltage output; zero return interlock; connector for remote safety interlock; high voltage circuits and external load protected by fast-acting magnetic circuit breaker; primary circuit protected by thermal overload breaker; cabinet and panel at ground potential.

Housed in a welded steel cabinet with cable reel, detachable push-handle and semi-pneumatic wheels. Dimensions are: 23" wide, 21" deep, and 41" high. Weights range from 150 to 250 pounds. (Fig. 3).

Optional features include: Multiple kilovoltmeter ranges, milliammeter, secondary overload circuit breaker with adjustable limit or dual range, and burn test circuit.

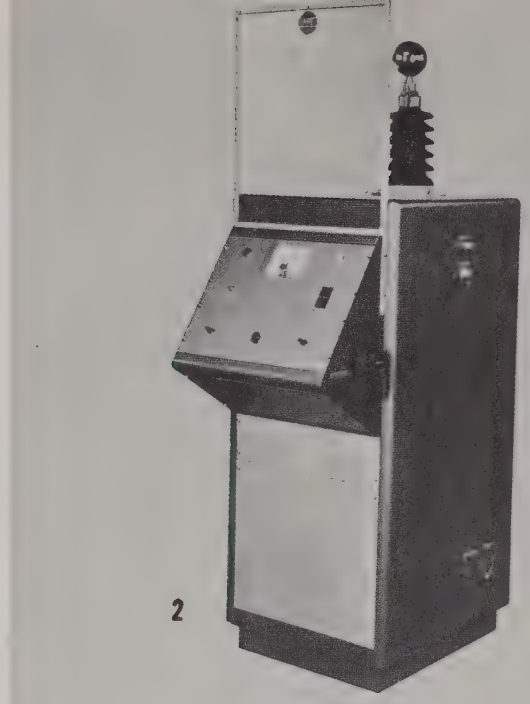
## Mobile D-C HYPOTS® . . to 120 KV, 10 MA

Heavy-duty mobile test sets for determining insulation leakage and dielectric strength of cables, bushings, switchgear, transformers, motors and generators . . . on the factory floor, outdoors, or in mines and quarries.

Outputs continuously variable from 0 to 45 kv and on up to 120 kv, with ratings of 2.5, 5, 10 ma, at full voltage. Operate from 115 v, a-c. High voltage receptacle may be oil filled for corona-free connection. The mobile cabinets are similar in design and dimensions to those listed for the "Mobile A-C HYPOTS®." Weights range from 285 to 450 pounds.

Standard features include: 4½" kilovoltmeter connected directly across the high voltage output; three-range 4½" microammeter electronically protected against overload; zero return interlock; connector for remote safety interlock; fast-acting magnetic circuit breaker in output to protect high voltage circuits and external load; thermal overload breaker to protect input circuits; long-life selenium high voltage rectifiers; metered return and bypass return terminals for measurement of load (leakage) or bypass (guard) currents.

Optional features include: Multiple output voltage ranges, vacuum tube microammeter with ranges as low as 2 microamperes, full scale, reversible polarity, adjustable high limit shut off for voltage and current.



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## "Thumper" Cable Fault Locator

"Thumper" Cable Fault Locator converts the high voltage, low current output of a d-c high potential test set into high-voltage (up to 25 kv) high-current impulses to allow ready location of faults in electrical power cables. The frequency and intensity of the high-current impulses are adjustable while the "Thumper" is in operation. A 25-kv model is available as an accessory unit for use with suitable high potential d-c testers. Smaller units may be incorporated as a built-in feature in many of the D-C HYPOTS®. Descriptive bulletin is available.

# Bench and Portable Models

## Bench Type D-C HYPOTS® . . to 45 KV, 25 MA

Output voltages continuously adjustable, zero to maximum of 5 kv to 45 kv, and full load current ratings of 100 microamperes to 25 milliamperes or more. The steel bench-type cabinet is same as described for Bench Type A-C HYPOTS®. (Fig. 6).

Standard features include: 4½" kilovoltmeter directly across the high voltage output; three-range current meter electronically protected against damage from overload; fast-acting circuit breaker in output; thermal overload breaker in primary; long-life selenium rectifiers; grounded panel and cabinet; zero return interlock; connector for remote safety interlock; metered return and by-pass return terminals allowing measurement of either load or guard currents.

Optional features include: multiple voltage ranges; adjustable circuit breaker; vacuum tube microammeter with ranges as low as 2 microamperes, full scale; adjustable high limit voltage or current shut off; and automatic rate of rise (see page 4).

## Bench Type A-C HYPOTS® . . 35 KV, 2 KVA

These high potential test sets are suited for dielectric strength testing of insulating materials, sample lengths of wire and cable, and components . . . having relatively low distributed capacitance.

Outputs available continuously variable from 0-10 kv, up to 0-35 kv, at 1 or 2 kva rating. The steel cabinet is finished in grey baked hammertone, and sloping aluminum panel in blue hammertone. Dimensions are: 20" wide, 16¼" deep at base, and 14¾" high plus output bushing. Weights from 70 to 100 pounds. (Similar to Fig. 6).

Standard features include: 4½" kilovoltmeter directly across the high voltage output; cabinet and panel at ground potential; fast-acting circuit breaker in output and thermal overload breaker in primary; zero return interlock; connector for safety interlock.

Optional features include: multiple kilovoltmeter ranges; output current meter with single or multiple ranges; dual range or adjustable secondary overload circuit breaker; adjustable leakage indicator light; automatic rate of rise control (as described on page 4).

## Portable D-C HYPOT® . . 5 KV, 2 MA

Output of the Model 5205 Portable D-C HYPOT® is continuously variable from 0 to 5000 v d-c, metered in the output circuit. Measures leakage current as low as 0.05 microamperes over four scale ranges: 0-2, 20, 200 and 2000 microamperes.

Operates from 115 v a-c, with selenium rectifier providing up to 15 ma for rapid charging of capacitance loads. The welded steel case has a removable lid and carrying handle. Measures: 13½" wide, 13" high, and 7" deep. Weighs 24 pounds. Descriptive bulletin available.

## "HYWATT" A-C HYPOT® Jrs. . . to 10 KV, 2 KVA

For a-c dielectric strength testing to 10,000 v at 2 kva, this HYPOT® series offers economy and the convenience of a compact bench-type cabinet. (Fig. 5). Models are available with output continuously variable from 0 to 1500 v up to 10,000 v a-c, at continuous duty ratings of 0.5 to 2 kva (approximately double for intermittent duty).

Features include: 4½" kilovoltmeter connected across the output, overload protection in output and primary circuits, high voltage "ON" switch allows momentary or sustained application of test potential. Descriptive bulletin available.

## A-C HYPOT® Jrs. . . to 10 KV, 230 VA

Portable a-c dielectric strength testers providing outputs continuously variable from 0-1500 v up to 10,000 v a-c. Use of neon breakdown and leakage current indicators in conjunction with collapsing field-type high voltage transformers results in an instrument that is rapid and safe for production testing.

The leakage current indicator is adjustable from 0.3 to 3 ma. A 4½" kilovoltmeter directly across the high voltage output provides high accuracy. Short-circuit current cannot exceed 18 ma. The cabinet and panel are at ground potential. (Fig. 4).

Optional features include: Leakage indicator light adjustable to as low as 0.1 ma or as high as 5 ma; retractable tip or stationary test prods. Detailed specifications for each model are available.

**D-C HYPOT® Jrs. . . .** compact, portable insulation leakage current testers have high voltage selenium rectifier, providing output variable from 0-1500 v, and up to 5000 v d-c at 2 ma. Short-circuit current limited to 15 ma. Case and panel similar to illustration for A-C HYPOT® Jr. Descriptive bulletin available.

## HYPOT® Jr. Automatic "Squawker" Models

Available with output voltages from 0-1500 volts to 0-6000 volts a-c. These units are similar to the standard HYPOT® Jr. models except that an audible signal unit and external control terminals are included, which operate simultaneously with the visual indicator.

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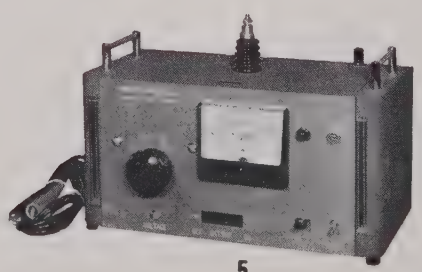

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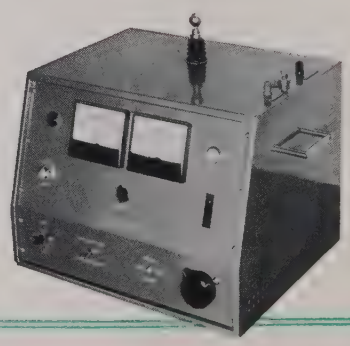


# HYPOTS® for Special Applications

## Insulating Materials Testers

Listed below are representative ARI testers for solid and liquid insulating materials. Due to the rapid progress of insulating materials and testing techniques, new equipment is added whenever required to meet ASTM, MIL and Federal test specifications.

### Model 4712 Oil and Materials Tester

Provides 0 to 60 kv at 2 kva a-c, to test insulating oils and materials. Complete with safety interlocked test cage, oil cup and U.S., English and German standard electrodes. The rapid-acting magnetic breaker in the output has two sensitivity settings, facilitating tests at lower voltages. Housed in steel console cabinet with panel and cabinet grounded for operator safety.

### Model 4510 Insulating Materials Tester

Test potential continuously variable from 0-50 kv a-c, at 2 kva. Numerous automatic control features facilitate testing insulating materials.

Test cage of transparent plexiglas accepts all ARI materials test fixtures and is safety interlocked to allow full view of the sample under test. Caster-mounted console cabinet. (Fig. 10).

Motor-driven rate of rise is adjustable from 300 to 3000 volts per second. Also dwell time on test sample is timer controlled and adjustable. The output kilovoltmeter has an electronic memory circuit retaining the indication on the voltage at which breakdown occurred. Descriptive bulletin available.

### Model 4501 Materials Testing HYPOT®

Meets the dielectric strength testing requirements of Specification D-149, ASTM Standards on Electrical Insulation Materials. (Fig. 9). Output continuously variable from 0-35 kv a-c at 2 kva (intermittent rating). Magnetic breaker trips when specimen breaks down. Output termination in jacks at center of the lucite cabinet top accepts the interchangeable ARI materials testing fixtures. Optional features: interlocked clear lucite test cage and selection of ARI plug-in materials testing fixtures, automatic rate of rise, dual sensitivity circuit breaker, etc.

### Model 4505 Insulating Oils Tester

Provides dielectric strength testing of insulating liquids in accordance with ASTM and Federal Specifications. REA approved. Output is continuously adjustable from 0-35 kv at 2 kva, a-c. Other voltage and power ratings are available. (Fig. 8).

Has 4½" rectifier type kilovoltmeter, magnetic breaker in output, zero return interlock, removable oil cup with standard ASTM 1" adjustable flat electrodes, bench type cabinet and carrying handle. Measures: 16" wide, 8½" deep and 8" high. Weight: 42 pounds. Motor driven rate of rise, dual sensitivity breaker and lucite test cage may be supplied. Descriptive bulletin available.

### Model 8540 Arc Resistance Tester

Tests arc resistance of solid insulating materials in accord with ASTM Specification D495-58T. Arc intensity and duration are adjustable. Internal blower for exhaust fumes. Jig for sharpening test electrodes is included. Descriptive bulletin available. (Fig. 7).

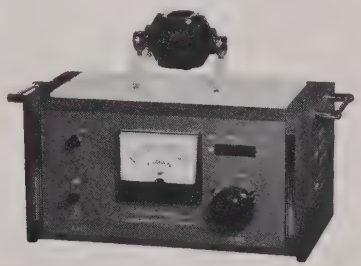
### Corona Test Equipment

Detects and displays the presence of corona on built-in oscilloscope—caused by internal voids, insufficient clearances or other defects in material or equipment.

Equipment includes: specially constructed corona-free HYPOT® test set; a pick-up device to extract the true corona voltage; and the corona detection display unit. These sections are available as individual units or as an integrated package built into the ARI standard deluxe control cabinet. Outputs of 20, 30 and 35 kv are standard, although up to 100 kv may be supplied.

### HYPOT® Power Supplies

HYPOT® designs provide a wide range of power supplies for special applications. D-C outputs to 250 kv and a-c outputs to 150 kv are available with current ratings from microamperes to amperes. Regulation and ripple characteristics can be supplied to suit your needs. A wide choice of housings is available.



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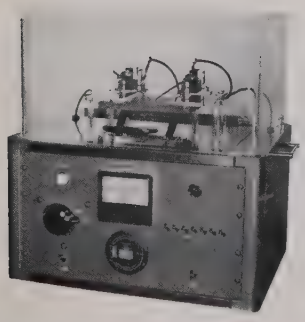

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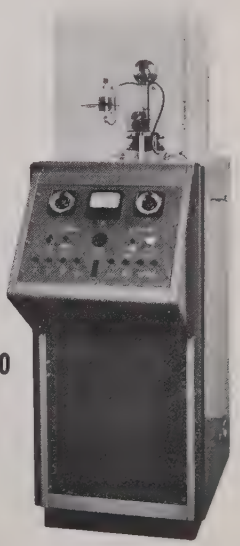

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# VIBROTEST® Megohmmeters

## Measure Insulation Resistance to FIVE MILLION Megohms

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### The Modern Megohmmeter

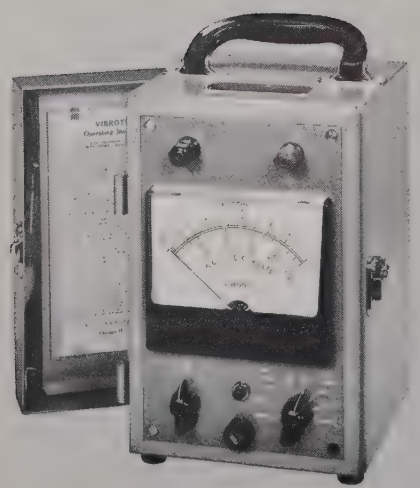
Model 2570 VIBROTEST® Megohmmeter is a portable, a-c line-operated instrument providing direct-reading measurement of resistance to 5,000,000 megohms at 500 v d-c test potential.

There are six scale ranges: 1 to 50, 10 to 500, 100 to 5,000, 1,000 to 50,000, 10,000 to 500,000 and 100,000 to 5,000,000 megohms.

The 4½" rectangular meter is calibrated from 1 to 50 megohms. The power supply uses long-life selenium rectifiers, eliminating batteries or cranking. Use of five gas diode regulator tubes assures constant test voltage despite line voltage variations from 105 to 130 v.

The instrument has a welded steel case finished in grey hammertone and a removable lid with carrying-handle. Size is 8⅞" by 6" by 8½". Weight, 11 pounds. (Fig. 11). Descriptive bulletin is available.

Model 250 VIBROTEST® Megohmmeter is similar to the Model 2570, except that four megohm measuring ranges are provided: 1 to 50, 10 to 500, 100 to 5,000 and 1,000 to 50,000 megohms.



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### VIBROTEST® Megohmmeters

### for Maintenance and Production Testing

A wide selection of direct reading, push-button operated megohmmeters is available in the various VIBROTEST® models that are designed for maintenance and production testing of insulation resistance. Many incorporate low ohms ranges for measuring continuity as well as ranges for measuring a-c and d-c voltages.

Operation is from self-contained batteries which, through a unique synchronous vibrator circuit, produce test potentials of 125 to 1000 v d-c for dependable measurement of insulation resistance. All models are housed in welded steel portable cases with carrying handle and removable lid. Case and lid are finished in grey hammertone, with the panel in blue hammertone. (Fig. 12).

Special models are available for the specific requirements of electric utility service, railway control and signal (to A.A.R. Specifications) and for marine use. Complete descriptive bulletins are offered.

HOSPITAL OPERATING ROOM SAFETY . . . The VIBROTEST® Model 269 has been designed to meet N.F.P.A. Specifications for measuring conductivity of hospital operating room flooring, conductive footwear, castors and other devices to assure safety from explosions resulting from electrostatic discharges. Descriptive bulletin available.

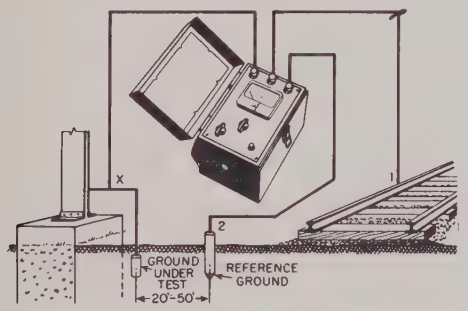
# VIBROGROUND . . Measure Ground Resistivity

## Resistance of Man-Made Grounds

VIBROGROUND® is the fast, accurate way to test man-made grounds for electrical and electronic systems. Ground resistance measurements made with VIBROGROUND® are direct reading and require no computations.

These instruments provide readings of actual resistance to earth of the ground connection, unaffected by stray a-c or d-c voltages and currents, as well as by length of test leads, resistance of prods and general soil conditions. All models are push-button operated with self-contained batteries and synchronous vibrator power supply. No cranking or leveling.

VIBROGROUND® Models 251, 255 and 259 provide ranges covering every requirement by utilities, telephone companies, lightning protection engineers and similar applications for measuring man-made grounds. Descriptive bulletin available.




## For Corrosion Control Engineers

**. . push-button measurement of soil resistivity, anode resistance, circuit resistance, polarization effects**

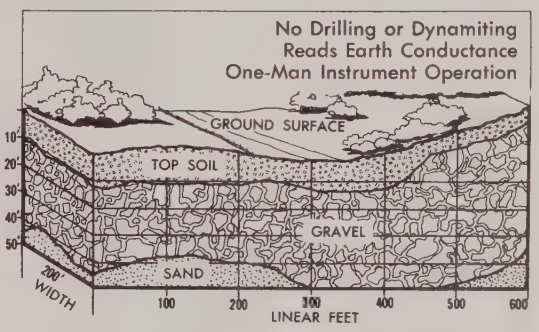
VIBROGROUND® Models 263A and 293 provide lightweight, accurate instruments for dependable measurement of soil resistivity and ground resistance . . . that operate from self-contained batteries and synchronous vibrator power supply. Complete accessories are available for two, three and four electrode methods of measurement.

Selector switch choice of ranges: 0-1, 0-10, 0-100 and 0-1000 ohms on the Model 263A and 0-1, 0-10, 0-100, 0-1000 and 0-10,000 ohms on the Model 293. Housed in welded steel case with removable cover and carrying handle. Weight 10 pounds with cover removed. (Fig. 13). Descriptive bulletin available.

## Geophysical Subsoil Exploration

Electrical geophysical subsurface exploration through the use of the several VIBROGROUND® models designed for such applications . . . has received wide acceptance in many fields ranging from prospecting for mineral ores to determining subsoil profiles in connection with highway, bridge, pipe line and building construction. One of the most important applications is the wide use in highway construction and location of gravel deposits.

The VIBROGROUND® instruments for geophysical exploration provide direct readings of soil resistivity (in the case of the Model 274M, soil conductance) and are available with suitable accessory equipment for all methods of testing. These instruments are self-contained, light in weight and operate from a self-contained battery through the unique synchronous vibrator power supply. Descriptive bulletin available.

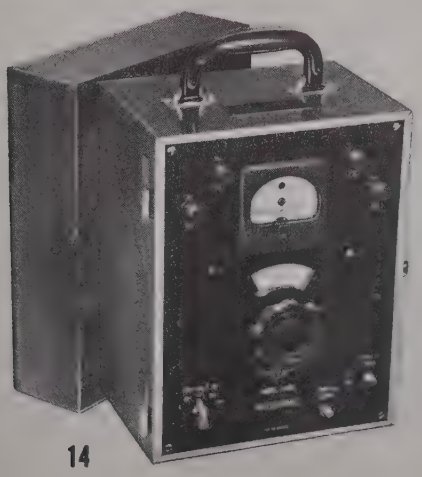



## The "MICHIMHO" VIBROGROUND®

The above illustration is a subsoil profile prepared from soil conductance readings taken with the Model 274M "MICHIMHO" VIBROGROUND® . . . developed to utilize the Barnes Layer Method of subsoil determination.

This world-recognized procedure for determining the profile of subsoil layers provides data for solution of problems connected with location of highway grades, bedrock determinations, drainage slopes, and location of sand and gravel pits. The low cost of these determinations and the speed with which they can be made affords an important advance over seismographic methods and test drilling. (Fig. 14). Complete descriptive bulletin available.





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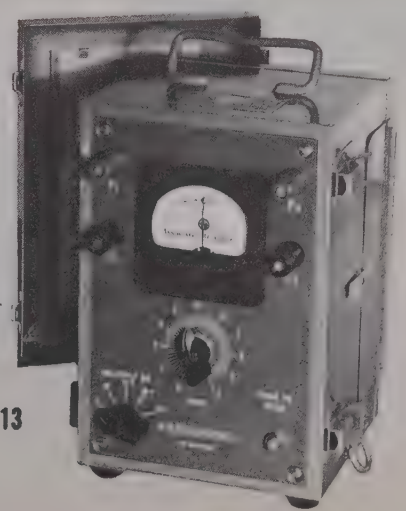

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# Instruments for Special Applications

## Automated Production Test Resistance Bridges

Model 8516 "Pilotal" Ohmmeter automatically measures resistance to close tolerances and rejects when high or low limits are exceeded, by means of indicator lights. It also actuates circuits for automatic rejection, discriminating between samples that are on the high or low side. Figure 15 illustrates the Model 8516 as set to reject with 1% accuracy at a low limit of 3.75 ohms and a high limit of 4.00 ohms. The instrument may be supplied to accept or reject at resistance values from a fraction of an ohm to 5 megohms. Test voltage is low to assure operator safety. Complete application data is available on request.

Model 8513 Pilotal Resistance Bridge may be preset for any resistance value from 1 ohm to 10 megohms (accuracy better than .1%). Models may be provided with separately adjustable high and low limits from .2% to 20%.

## Automated Production Test Capacitance Bridge

Model 8529 Pilotal Capacitance Bridge shown in Fig. 16, permits automatic production testing of all types of capacitors. Center value adjustable from .001 to 1 microfarad with preset acceptance limits of ± 1% to operate go and no-go lights. Models may be furnished incorporating separately adjustable high and low limits from .5 to 20%.

## Phase Sequence Indicator

A miniaturized pocket portable instrument that provides positive phase sequence indications when connected to three-phase power sources. The instant readings not only assure proper rotation of motors but guard against costly damages. This instrument weighs only 11 ounces and measures 2⅞" wide, 1⅝" deep and 4" high.

Model 40 is designed for use on 60-c circuits, and Model 44 is for use on 400-c circuits. (Fig. 17).

## Portable Precision Ohmmeter

### accurate to ½ of 1%

The accuracy of ½ of 1% provided by these ARI Precision Ohmmeters is up to four times improved over that of usual portable instruments . . . yet they are direct reading and retain their accuracy under severe usage.

Compensation is provided for changes in resistance of leads and battery. The welded steel case and removable cover are finished in baked grey hammertone. (Fig. 18).

Model 244 provides ranges: 0-50/500/5,000/50,000 ohms, permitting readings as low as 0.05 ohm.

Model 246 provides ranges: 0-100/1,000/10,000/100,000 ohms with readings as low as 0.1 ohm.

## Sphere Gap Assemblies

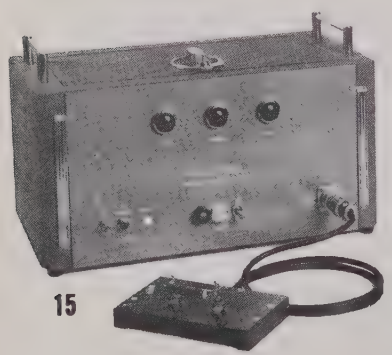
This is one of the few recognized standards for measuring high voltage. Since the calibration accuracy of a sphere gap depends upon physical configuration rather than upon electrical characteristics of the components, calibration accuracy may be positively determined by use of this device.

The ARI Sphere Gap Assembly consists of the sphere gap with micrometer gap adjustment (direct reading in inches or centimeters) and a current limiting resistor assembly. Models are available to measure potentials from 30 to 150 kv. (Fig. 19).

## Portable Kilovoltmeters

These portable kilovoltmeters measure true peak (positive, negative or both) rms, or d-c . . . or any combination of these in single or multi ranges.

Ranges from 10 to 150 kv peak or d-c, and from 10 to 110 kv rms are available. Accuracy is better than 3% of full scale. Current drawn from a circuit under test is less than 0.5 ma. (Fig. 20). The ARI Engineering Staff will supply additional data on your application.



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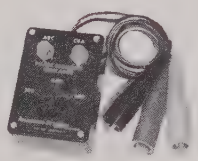

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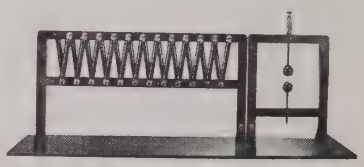

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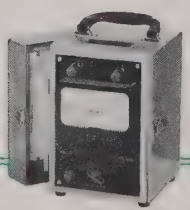

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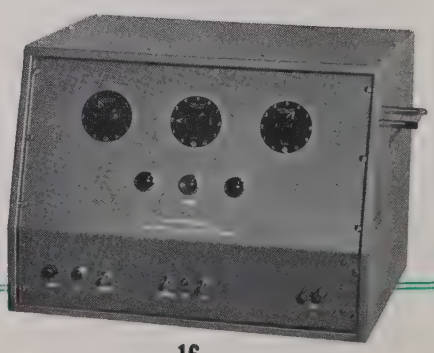

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## Automated Operation of Tests for Components, Cables, Materials

The ARI Engineering Staff is prepared to design and build special purpose complex automatic sequence and sensing test systems that embody high potential breakdown, insulation leakage current measurements, continuity and associated tests.

Figure 22 shows a special HYPOT® arranged to sequentially test fifty items or circuits in a single assembly at d-c potentials up to 4000 v. The position under test is indicated on a counter. When leakage current exceeds a preset level, the tests stop simultaneously with the illumination of a warning light and sounding of an alarm.

The Model 8515 Automatic Capacitor Tester Fixture may be used in conjunction with the Model 8514 Automatic HYPOT®. This is a fully automated system for life testing 50 capacitors, with memory provision, cut-out of failures, fully motorized control of voltage rise, preset dwell time for high voltage test and many other unique facilities.

The Model 8524 High Voltage Automatic Analyzer, Fig. 21, and also illustrated on page 3, provides facilities for completely automated continuity, insulation resistance and dielectric strength testing of up to one hundred and twenty cable conductors, assembly circuits or components.

A bulletin is available detailing many more unusual systems for automated testing that have been designed and produced by Associated Research, Inc.

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## Current Transformers for Metering and Allied Applications

"Donut" type current transformers for metering and allied applications are available in turns ratios of 10/5 to 5,000/5 at burdens of 2.5 to 30 va and higher. Frequency response is from 25 to 400 cycles; insulated for 4000 v a-c; ratio accuracies of 1% are standard.

Inside diameter varies from 1⅝" to 3½", depending upon the model. However, any size or shape may be supplied to fit the customer's requirements.

The "Donut" current transformers are of the inserted primary type for positioning over the conductor or bus bar. Two secondary output leads are provided for direct connection to the meter or other external circuit. (Fig. 23).

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## The Keeler Polygraph (Lie Detector)

For twenty years Associated Research, Inc. has led in the development and manufacture of the polygraph, as an instrument essential to public safety and progressive law enforcement.

Today, ARI's Keeler Polygraph has become an important adjunct to industrial security and employee relations programs. If you would like more information on this subject, please write. (Fig. 24).

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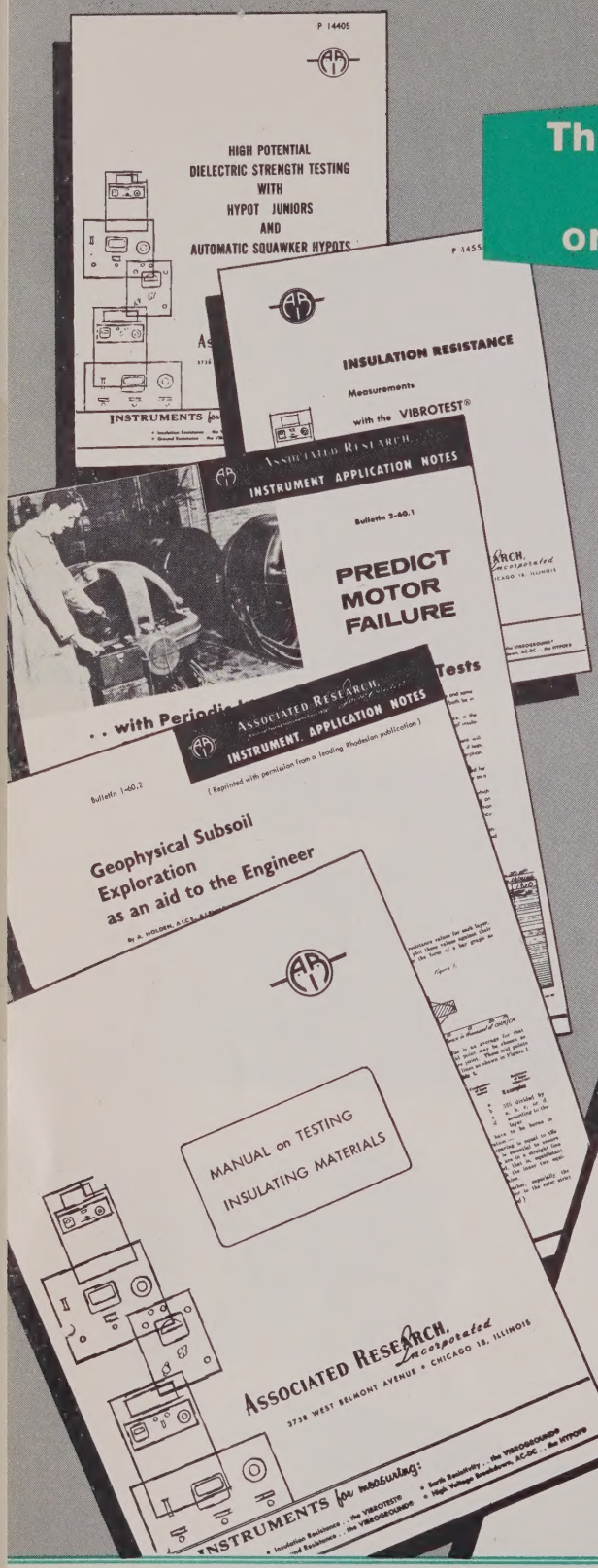
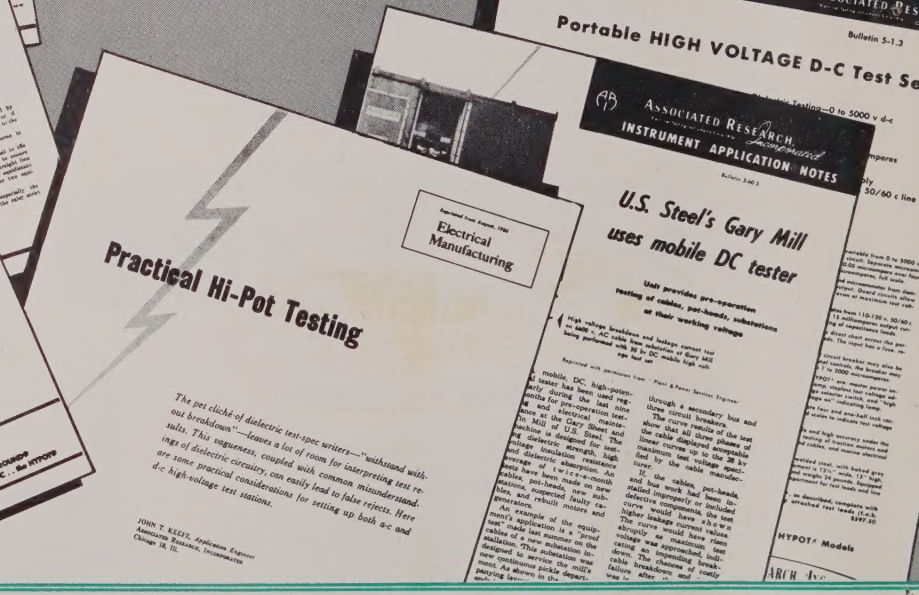
# These ARI Application Bulletins Offer Important Data on Use of Modern Instruments

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**Your inquiry will be appreciated for application data on any aspect of high voltage breakdown testing, insulation resistance or dielectric strength measurement.**


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